Nutrient and Nutrient Cycling Relationships Between Host Foliage and the Douglas-fir Tussock Moth

FINAL REPORT

Nutrient and Nutrient Cycling Relationships Between Host Foliage and the Douglas-fir Tussock Moth

Principal Investigator: J. Douglas Campbell, Eastern Oregon State College, La Grande

Cooperators: J. Michael Geist, USDA Range and Wildlife Habitat Laboratory, La Grande

Roy C. Beckwith, USDA Forest Service Laboratory 3200 Jefferson Way, Corvallis

Gerald S. Strickler, USDA Range and Wildlife Habitat Laboratory, La Grande

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SUMMARY

The influence of chemical composition of food sources on the dynamics of Douglas-fir tussock moth (DFTM) populations and the impact of the DFTM on nutrient cycling are the topics addressed in this exploratory study. DFTM frass, new and year-old needle growth on host trees and fallen needles collected within the study areas were the experimental materials. Methods were adapted for their collection, processing and analysis of the calcium, magnesium, potassium, phosphorus, sulfur and nitrogen content in each.

Samples of frass and host foliage (Douglas-fir and grand fir) collected in 1974 on the Umatilla National Forest in an area protected from DDT spraying were analyzed to determine quantitative relationships of the nutrient composition between the materials. DFTM populations in the study area were light, climaxing at about 20 larvae per 1000 square inches of foliage. Small amounts of new-growth needles were consumed; year-old growth was not visibly affected.

Nitrogen levels in frass were consistently lower than the new needle growth indicating that the larvae were utilizing the element. By contrast, calcium levels in the frass of third, fourth and fifth instars increased to well above the foliage levels suggesting that the older larvae expel a good portion of this element. High nitrogen levels coupled with low calcium levels in new-needle growth may be associated with the feeding preference demonstrated by DFTM larvae for new needle growth.

Our data show that the calcium content in year-old growth was higher than that in current needles. Nitrogen in new growth decreased rapidly to 50% of the June 27 level by July 25 (near the year-old needle level in both species).

Calcium content was more variable among individual trees in grand fir than Douglas-fir, but it was higher on the average in the former species for both needle ages. There was little difference between species in either new or year-old needle nitrogen concentrations/ was noted.

A major portion of the exploratory study was directed towards determining the impact of DFTM populations on nutrient cycling. Quantities of frass and needles dropped during the summers of two consecutive years were measured and variations in the amounts of individual nutrients deposited were compared. In the second year, which was the year of heavier DFTM population, trends in the amounts of nutrients deposited were contrasted. The latter objective included the fall-winter period to allow for a complete annual picture of nutrient deposition patterns. The nutrient cycling impact work was made possible enabled by the sample collections made in 1972, 1973 and 1974 at High Ridge on the Umatilla-Barometer watershed by Gerald S. Strickler.

points (see p. 2) ?

It is assumed that fallen-needles and frass are the primary phase of nutrient cycling affected by DFTM.

A 2 to 16 fold increase in the amount of frass deposited from 1972 to 1973 was observed while needle drop increases ranged from 1.2 to 2.3. All frass-nutrient amounts and most of the needle nutrient amounts increased substantially from 1972 to 1973 as well.

In 1973 nutrients in frass accounted for 25 to 48% of total for each nutrient deposited over the July to September period. Further, nutrients in frass accounted for between 8 and 27% of the amounts deposited from August, 1973 to August 1974. The impact of DFTM on needle nutrient deposition could not be differentiated in a quantitative fashion from normal needlefall.

This data is some of the first to be reported concerning seasonal variations in foliar nutrients and nutrient relationships between DFTM frass and host foliage. It provides some insight into the impact of the DFTM on nutrient cycling. The expectation is that this data will ultimately be used in modeling impacts of the DFTM on coniferous stands and that it will aid in making decisions concerning stand management.

INTRODUCTION

The effects of host nutrient levels on the feeding patterns and population dynamics of various forest insects has attracted considerable attention in recent years. Soil fertility (Mitchell and Paul, 1974), weather stress (White, 1974), and changes in the quality of phloem sap (Parry, 1974) are among the variables that have been examined to determine their influence on nutrient composition of insect food and the subsequent effect on the fecundity of several species of insects inhabiting coniferous forests. However, published research on relationships between nutrient levels and Douglas-fir tussock moth (DFTM) populations is scant. Such information as this is needed to better understand the population dynamics of this major forest pest in relation to food qualities and preferences. We expect that this knowledge could aid land managers in classifying stands into risk categories, manipulating risk status of forest stands through silviculture, predicting population trends based on stand composition, and in making artificial control decisions.

The increase of tussock moth populations in Northeast Oregon to outbreak proportions in 1972-1973 afforded the opportunity to conduct an exploratory study of quantitative relationships between tussock moth populations and nutrient concentrations in foliage and frass. The field portion of the study (sample collection and preliminary preparation of the samples for chemical analyses conducted by Campbell, Beckwith and Geist) was funded in 1974.[1] Samples of frass and foliage were obtained from Douglas-fir and grand fir at Simerson Springs on the Umatilla National Forest near La Grande, Oregon. The objectives

1. Cooperative Aid Research Agreement, Supplement No. 2, Supplement to the master memorandum of understanding between Eastern Oregon State College and the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. "Exploratory Study of Tussock Moth Frass and Litter Production Under Douglas-fir and Grand Fir Trees."

of the Simerson Springs Study, hereafter referred to as Phase 1 of this report, are as follows:

1. What relationships exist between the nutrient composition of fir tree needles being consumed by tussock moth larvae and the nutrient composition of DFTM frass?

2. How does the nutrient composition of the new needle growth compare to that of the one-year-old needle growth, and what is the contrast in seasonal trends in nutrient composition of new and year-old growth? (This objective was added after field collections began.)

3. What differences in nutrient patterns are observed between Douglas-fir and grand fir needle growth and frass?

In 1974, another research group under the direction of Gerald S. Strickler, La Grande Range and Wildlife Habitat Laboratory, was continuing forest litter collections begun in 1972. Strickler's study area at High Ridge on the Umatilla National Forest was unexpectedly infested by the tussock moth, and measureable amounts of frass were deposited in his litter traps. The magnitude, method and fortuitous timing of the Strickler collection provided the opportunity to broaden the scope of the exploratory study by supplying data that pertains to the implications of ecosystem nutrient cycling associated with insect outbreaks.

The High Ridge collection is the focal point of Phase 2 of this report. It is assumed that frass and needle litter were the points of nutrient cycling most affected by DFTM. The objectives of Phase 2 are as follows:

1. What differences in nutrient deposition via DFTM frass and needle fall occur during two consecutive growing seasons - one year prior to the outbreak and the year of major outbreak?

2. How do the amounts of nutrients deposited during the summer compare with frass and needle-fall nutrient deposition in the same area during the subsequent fall-winter period?

The analytical portion of the exploratory study (Phase 1) plus the sorting and analysis of Strickler's Samples (Phase 2) was funded by the USDA Douglas-fir Tussock Moth Research and Development Program in 1975.

Phase 1 (Simerson Springs Collection)

Methods and Materials:

Frass-litter samples were collected over eleven two-week periods during the months of June - November, 1974, in traps placed beneath each host tree. (Tables in Appendices 1 - 5.) Trap contents were dried at 65° C for twenty-four hours and were hand sorted to isolate the frass which was ground to less than 40 mesh by a Wiley or ball mill and stored in plastic vials at room temperature.

Foliage was collected at midcrown from each host tree on the same days the traps were emptied. Needles were clipped from the stems, dried, ground (as above) and stored in glass bottles at room temperature.

New needle growth on the two host species was the only foliage sampled during the first three collection periods (I-III). A decision to collect year-old needles to compare with new was made at collection IV, and objective 2 was added to this study phase. DFTM larvae prefer new needle growth when it is available, however third and later instars can feed on older foliage when high population levels exhaust new needle biomass (Beckwith, 1976).

Spectrophotometric methods were employed to determine six nutrients: calcium, magnesium, potassium, phosphorus, sulfur and nitrogen (Appendix VI). At least 0.35 grams of ground material (minimum of 0.7 grams unground) was required to obtain accurate analysis for all six nutrients in a given sample. One portion of each sample was analyzed for nitrogen via Kjeldahl digestion and the other portion for the remaining five elements using hot perchloric acid - nitric acid as the digest medium. (Nitrogen was the only nutrient determined when the ground sample weighed between 0.05 and 0.35 grams.)

Results of Phase 1:

The changes in concentration of the six nutrients in the frass and needle growth samples over time (collection date) are presented in Tables 1 through 16 and figures 1-12 (Appendix VII). Each figure displays the mean and range of nutrient concentration for the four sample trees by species and collection. Values for frass represent averages over each collection period while foliage data reflect the nutrient concentrations existing in the needle growth at the time of collection. Plotted values for frass and needle growth samples were offset to avoid confusion between ranges in the data.

Frass collection weights in 1974 were light because the larval population near Simerson Springs did not reach the high level that was typical in outbreak areas at nearby locations the previous year. A choice was required in several cases as to which analyses would be made. Nitrogen was ranked highest in priority partly due to its suspected nutritional importance and partly due to the greater sensitivity of the analytical technique employed. Consequently, frass analyses for calcium, magnesium, phosphorus, potassium and sulfur were made on collections III, IV and V only, while nitrogen was determined in frass samples from collections II through VIII.

Nutrient concentrations in new and year-old needle growth (Collections IV - XI):

New Douglas-fir needle growth from collections IV to XI was found to contain mean concentrations of nitrogen averaging 10 percent lower than that in the year-old needle growth (Appendix VII, Figure 1). The average calcium content was 30-40 percent lower (Figure 3), while potassium was consistently 10 percent higher in new growth than in the old (Figure 11). Sulfur concentration differences were inconsistent but tended to be 5 to 10 percent lower in the new growth (Figure 7).

The mean concentrations for phosphorus and magnesium varied only within a few percent between the two ages of Douglas-fir needle growth throughout the collection series (IV to XI) (Figures 5 and 9, respectively).

In grand fir the mean concentrations and ranges for the nitrogen content of new and year-old growth from collections IV - XI were essentially identical (Figure 2). Calcium means were consistently 30 to 40 percent lower in the new growth (Figure 4). Phosphorus means were consistently higher in the new growth by 20 percent (Figure 6). Potassium means were 10 percent higher in the new growth for the last five collections, but considerable overlap of ranges occurred (Figure 12). Magnesium and sulfur concentration differences between new and year-old needle growth were inconsistent - higher in the new growth in some instances and higher in the year-old growth in others - and the ranges of values in all cases overlapped significantly (Figures 10 and 8, respectively).

From collection IV through XI concentrations means for nitrogen, calcium and sulfur (Figures 1, 3 and 7) in both ages of Douglas-fir growth were relatively constant (± 15 percent deviation from the average mean value). Phosphorus, potassium and particularly magnesium follow patterns that are roughly parallel (Figures 5, 11 and 9, respectively).

Similar to the Douglas-fir results the concentrations means for nitrogen (Figure 2) in new and year-old grand fir growth were constant within a rather narrow range from collection IV through XI. Calcium and sulfur (Figures 4 and 8) in grand fir showed a slight increase up to collection IX and dropped off slightly in collections X and XI. As in the Douglas-fir results phosphorus, potassium and magnesium concentration means increased on the average beginning with collection VI and subsequently declined from collection IX to XI (Figures 6, 12 and 10, respectively).

Contrast of nutrient levels and trends between host species' needle growth (collections I - XI):

In all instances the concentrations of the six nutrients were consistently higher in the new needle growth of grand fir than in new Douglas-fir needles.

The concentration means for nitrogen in the new growth of grand fir were 10 percent higher on the average than for Douglas-fir. Both species show a pronounced drop in mean nitrogen concentrations from collection I to III. The year-old growth for both host species contained from 11,000 to 12,000 ppm nitrogen in collections IV-XI.

The trends for calcium in new and year-old needle growth in the two host species were very similar, but concentration means were two to three times higher in the grand fir. Furthermore, whereas the calcium concentrations in the new needles of both species increased from collection I to collection IV (the early larval feeding period), the trend was much more pronounced in grand fir.

The most noticeable difference in phosphorus concentration means between the two species was seen in the new growth which had concentrations that were 15 to 25 percent higher in the grand fir. Both species showed a substantial decrease in phosphorus from collection I to III. Year-old growth in both species had strikingly similar concentration mean values and trends.

Potassium concentration means in new and year-old growth ranged in value from 15 to 25 percent higher in grand fir than for Douglas-fir. The early season new growth from both host species displayed a rapid decrease from collections I to III.

In the latter part of the season, beginning with collection V, concentration mean values for magnesium were 20 to 30 percent higher in both ages of grand fir needle growth than in Douglas-fir. Concentrations in both species were smaller in collection I and increased gradually until collection IX.

Sulfur concentration means in grand fir new growth were 15 percent larger than in Douglas-fir. An early season decline in sulfur was reflected in the concentration means for collection I through III for both host species.

Frass results:

Mean concentrations of nitrogen in the frass collected were consistently 20 to 30 percent lower than in either the new or year-old needle growth in both host species. With the exception of collections II and III the mean concentrations of nitrogen in frass from Douglas-fir feeding were within a few percent of the means for frass from grand fir. In collections II and III nitrogen fluctuations were more dynamic for Douglas-fir frass - from 10 percent higher than grand fir frass at collection II to 28 percent lower at collection III. Frass nitrogen levels followed trends similar to new needle growth nitrogen levels although the rates of change were not alike.

There were only three collection periods (III, IV and V) having adequate frass for analysis of nutrients other than nitrogen.

In one two-week period the calcium content in frass increased from a mean concentration level equal to that in the new growth of both hosts (collection III) to a level 2.75 times higher than the Douglas-fir new growth level and 1.7 times that for grand fir new growth (collection IV). Throughout the three collection periods (III-V) the mean concentration of calcium in grand fir frass remained 6000 ppm above that in Douglas-fir frass.

The mean concentration of phosphorus in frass collected under the Douglas-fir was 16 percent lower than new Douglas-fir growth at collection III, 41 percent lower at IV and 21 percent higher at V. In grand fir, the mean concentration of phosphorus in frass was 5 percent higher than the new grand fir growth at collection III, 37 percent lower at IV and 6 percent lower at V. The contrast in phosphorus

levels in the frass between host species showed that the phosphorus mean concentration in grand fir frass varied from 560 ppm higher (III) to 160 ppm higher (IV) to 100 ppm lower (V) than Douglas-fir frass.

Potassium levels in Douglas-fir frass varied from 10 percent above the new Douglas-fir growth mean concentration at collection III to 40 percent below at IV and 23 percent above at V. Grand fir frass was 17 percent higher in potassium than new grand fir growth at collection III, 24 percent lower at IV and 24 percent higher at V. The mean concentration of potassium in grand fir frass was 800, 1300 and 900 ppm (approximately 10, 25 and 15 percent, respectively) higher than Douglas-fir frass in collections III, IV and V, respectively.

The mean concentrations of magnesium in Douglas-fir frass were lower than new Douglas-fir growth in collections III and IV by 8 and 17 percent, respectively. The mean value for collection V shifted to 7 percent above. Grand fir frass was 3, 5 and 37 percent above the new grand fir growth for the three collections. The overlap of concentration ranges between the frass and foliage, however, is extensive in both species. The average magnesium content in grand fir frass was higher than that in Douglas-fir frass by 280 (III), 300 (IV) and 430 (V) ppm for the three collections.

Sulfur concentrations in the frass ran generally within the ranges of both ages of foliage in the host species. Concentration means differed between hosts as follows: 290 ppm higher in collection III and 20 and 30 ppm lower in IV and V for grand fir frass as compared to Douglas-fir frass.

Phase 1 Discussion:

A point needs to be realized at the outset of this discussion that relationships between frass and needle growth may not be regarded as valid unless there is evidence that the larvae were feeding on that particular type of needle growth. In this study the population of DFTM failed to reach a level that would

have forced larvae to feed on anything but new needle growth. Only a small percentage of the new growth in the study area was affected. An apparently ample supply remained after pupation. Thus only the contrasts between frass and new needle growth are emphasized in this discussion. [The expectation is that the year-old needle growth data reported herein may be useful in interpreting impacts of higher populations.]

Interpretation of the data was hampered since, except for nitrogen, only three collection periods provided analytical information on frass. In addition, the ranges of the data overlapped substantially in many instances. Some elements show more overlap than others (Figure 1-12). Thirdly, the amounts of foliage consumed in relation to frass produced were not known.

The data for nitrogen suggest that DFTM larvae utilized this nutrient significantly. Of the six nutrients studied, nitrogen was the only one that was consistently lower in concentration in the frass than in all needle growth sampled over the collection period. Nitrogen has been identified by other researchers as being a crucial factor in maintaining the fecundity of herbivorous insect populations (White, 1974).

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Nitrogen may be a factor that entices young larvae to begin with new needle growth as a food source. Mean concentrations of nitrogen in new growth in both species were at the highest levels in the first collection (June 27, 1974) while the larvae were first and second instars. Analyses of the year-old growth were not obtained during this period (collection I-III) in our study, however, Krueger (1967) reported that nitrogen concentrations in year-old Douglas-fir needle growth were significantly lower at the time of bud burst than in new growth.

By collection IV nitrogen concentrations leveled out at a common value ($\pm$ 10 percent) for samples of new <u>and</u> <u>old</u> needle growth. Thus, while the larvae continue

to show preference for new growth as is observed for larvae of all ages (Beckwith, 1976), the influence nitrogen may have on the selection of new needle growth as a food source by third instar or older larvae is apparently diminished.

It is doubtful that the nitrogen level would have an influence on host preference between Douglas-fir and grand fir. The insect can develop equally well on the two species; however, the degree of acceptance of old-growth foliage at high population levels may govern early larval survival and ultimate tree damage (Beckwith, 1975). Mean nitrogen content of the new needle growth in the four Douglas-fir trees on the day of the first collection (first and second instars) was about 8 percent higher than that of the new needle growth in grand fir. Two weeks later the mean nitrogen content of the new Douglas-fir growth had dropped to about 5 percent below that in grand fir and remained below that of the grand fir for the rest of the season. // ref.?

Calcium analyses revealed that the mean concentration of this element fluctuated in a pattern that was different from trends for the other five nutrients. The contrasts are most striking between calcium and nitrogen. Whereas foliar nitrogen was apparently retained in large part by the larvae, calcium appears to have been substantially concentrated in the frass, particularly in collections IV and V. The mean concentration of calcium in year-old needle growth was consistently higher than in the new needle growth of both host species.

Mean concentrations of phosphorus and trends for new and year-old Douglas-fir growth and year-old grand fir growth were quite similar for collections IV - XI. Seasonal trends were comparable. Phosphorus in new growth in both species at the beginning of the season dropped precipitously from collections I to III, an observation also noted by Krueger for Douglas-fir foliage (1967). In frass the concentration of phosphorus decreased to an unexpected extent with collection IV.

Potassium in frass followed a pattern that was similar to phosphorus, but more pronounced. The drop in concentration was quite consistent with both nutrients.

Effects by weather cannot be ruled out. A check on precipitation records for the region during the collection periods revealed that there was no measurable precipitation during collections III and V, but 0.12 inches during period IV. (Weather records for Meacham, 1974, supplied by U.S. Meteorological Station, Pendleton, Oregon.) Soluble potassium and possibly phosphorus salts may have been lost, particularly from frass, by rainfall in collection IV. It is important to note, however, that summer thunder showers may have occurred in the immediate study area and may not have been recorded by the Meacham Station. We suspect that potassium salts would be most susceptible to leaching effects.

The seasonal trends for the magnesium concentration in the new needle growth of both host species were similar to the calcium trends in the same samples in the manner that they began at a lower level in collection I and increased gradually until collection IX. Of the six nutrients studied these two were the only ones exhibiting such a pattern through the early summer.

Such correlation between magnesium and calcium was not mirrored in the frass samples. Overlapping of the range of magnesium values for frass and new needle growth was substantial.

It is interesting to note that (with a few exceptions in the nitrogen, phosphorus and sulfur data) the mean concentrations for nutrients in all collections were higher by a substantial amount in the grand fir samples than in the Douglas-fir.

The largest seasonal fluctuations of concentration occurred with the most highly concentrated nutrients. Calcium (ranging up to 22,000 ppm in grand fir foliage and frass), nitrogen (up to 19,000 in new Douglas-fir growth) and potassium

(up to 10,000 in new grand fir growth) exhibited the more dynamic differences in trends and percentages as frass and new growth were compared. Magnesium and sulfur at their relatively small concentration levels were the least variable on a relative scale.

Phase 2 (High Ridge Collection)

Methods and Materials:

Frass and needle litter samples studied in Phase 2 were collected on High Ridge on watersheds 1 and 4 (G.S. Strickler, unpublished results). Watershed 1 is 30 acres (12 hectares) and watershed 4 is 35 acres (14 hectares) in area. A frass-litter trap (described below) was placed at every fifth point in 50 points on a 2 chain grid.

The stands were mixed and consisted of Douglas-fir, grand fir, subalpine fir, western larch and some lodgepole pine.

Watersheds 1 and 4 were selected from four High Ridge watersheds on the basis that they yielded samples containing the most frass per trap throughout the series of collection periods (see schedule below).

The traps were rectangular frames, 2.6 square feet (0.25 sq. meters) in area and 9 cm in depth. The bottom was 1.4 mm mesh galvanized steel screen. The sides were made of pine. The screen was held in place by a pine strip border, 3/8 inches thick, nailed to the frame. During collection the frame (and most of the wire screen) rested on the forest floor.

The collection schedule was as follows:

Collection Period	Day of Collection	Collection Number
Jul. 1 to Oct. 1, 1972	Oct. 2, 1972	I
Oct. 2 to Jun. 27, 1973	Jun. 28, 1973	II
Jun. 28 to Jul. 29, 1973	Jul. 30, 1973	III
Jul. 30 to Aug. 29, 1973	Aug. 30, 1973	IV
Aug. 30 to Oct. 1, 1973	Oct. 2, 1973	V
Oct. 2 to Jul. 31, 1974	Aug. 1, 1974	VI

On the day of collection the contents of each trap were placed in paper sacks and dried in a forced air oven at 65^{o} C for twenty four hours. The materials were separated by hand into several categories. The two categories

that were subsequently ground and analyzed according to the procedures described in Phase 1 were frass and fallen needles. Insect bodies and parts were not included.

Instrument readings for each nutrient (see appendix VI) were converted into concentration units of micrograms nutrient per gram tissue via computer (see Tables 17-20). Concentrations were multiplied by the amounts of frass or needle litter collected in each trap and the product was converted to kilograms per hectare for each watershed (see Tables 21-24).

Comparison of years 1972 to 1973 required calculation of weighted mean concentrations (Tables 17-20) over the period covering collections III, IV and V obtained in 1973 from each trap. For some of the traps, however, one or two of the three collections yielded little or no frass. This precluded chemical analysis in those instances. Some numbers were therefore treated as zeros. In such instances the weighted mean actually reflects only one or two collections.

Several sets of data were necessarily omitted from the composite results for phase 2, objective 1 (see Tables 25-28). Objective 1 makes a comparison of deposition data obtained for the summer season of 1972 (collection I) with that for the summer season of 1973 (collections III, IV and V). Thus it was felt a complete pairing of trap data between years by watershed was necessary. If any data was missing for a given trap in collections I, III, IV and V, the remaining trap data was also treated as missing.

On watershed 1 (see Tables 25 and 26) traps 20, 40, 45 and 50 yielded frass and needle material sufficient for analyses of all six nutrients, whereas only nitrogen analyses were possible for traps 5, 10 and 15. Therefore, the means listed in Tables 25 and 26 for calcium magnesium, potassium, phosphorus and sulfur are the average of only four traps' data; nitrogen means are averages of seven traps' data.

For watershed 4 (Tables 27 and 28) sufficient paired trap data to meet objective 1 of Phase 2 was obtained for all six nutrients in only two traps (40 and 50). Frass deposition on this watershed in 1972 was very light. The nitrogen means are based on eight traps (5, 20, 25, 30, 35, 40, 45 and 50).

In objective 2 seasonal trends in nutrient deposition (expressed as kilograms per hectare) are considered (Tables 31-45). Calculations of the mean values ($\overline{X}$) listed in Tables 31-42 are based on the data from those traps having complete sets of data on frass and fallen needles for collections III, IV and V. Watershed 1 means for calcium (Table 31), magnesium (Table 33), potassium (Table 35), phosphorus (Table 37), and sulfur (Table 39) are computed from six traps (20, 30, 35, 40, 45 and 50). Nitrogen means for watershed 1 (Table 41) are based on nine traps (5, 10, 15, 20, 30, 35, 40, 45 and 50). Watershed 4 means for all nutrients except nitrogen are determined from six traps (5, 30, 35, 40, 45 and 50) while nitrogen means (Table 42) additionally include traps 20 and 25.

Frass data for all nutrients except nitrogen are omitted completely for the winter - over period of 1973-74 (collection VI) due to the small amounts of material available to analyze. The frass collected was apparently carryover from prior feeding periods.

but not detected!!

Results of Phase 2, Objective 1:

Although it was initially planned to compare endemic vs epidemic population effects, amounts of DFTM frass contained in the traps indicated that more than endemic populations actually existed on the two watersheds in 1972. This was particularly true on watershed 1. Contrasts between years therefore represent contrasts in differing population levels.

We have assumed that loss of fine frass material from early instars through the trap screen mesh was proportional between years and had no effect on the degree of comparative increases.

Mean values for the amounts of nutrients deposited during the summer growing seasons of 1972 and 1973 are compiled in Tables 25-28. By comparing the 1972 means to those of 1973 we found the following:

1. Calcium deposited in frass on watershed 1 increased to 3.08 times the 1972 level; on watershed 4 by a factor of 13.56. Calcium deposited in fallen needles on watershed 1 increased slightly by a factor of 1.04 while on watershed 4 the increase was by a factor of 2.04.
2. Magnesium amounts for frass collected from watershed 1 in 1972 increased by a factor of 3.24; on watershed 4 by a factor of 15.79. Magnesium in fallen needles on watershed 1 increased by 1.17 times; on watershed 4 by a factor of 2.15.
3. Potassium deposited in frass collected on watershed 1 increased by a factor of 12.15 and on watershed 4 by a large factor of 72.8. In fallen needles the increase on watershed 1 was by a factor of 1.21 while on watershed 4 the increase was by 2.75 times.
4. Phosphorus from frass on watershed 1 increased in amount by a factor of 4.44 and on watershed 4 by 19.2 times. In needles the phosphorus increased 1.45 times on watershed 1 and by a factor of 2.89 on watershed 4.

5. Sulfur deposits in frass on watershed 1 increased by 4.05 times while the increase on watershed 4 was by a factor of 16.61. Sulfur amounts in fallen needles increased by a factor of 1.25 on watershed 1; on watershed 4 the increase was 2.46 times above the 1972 mean.

6. Nitrogen deposited in frass on watershed 1 increased by a factor of 2.84 and on watershed 4 by a factor of 20. The mean nitrogen amount in needles collected on watershed 1 went up by a factor of 1.59 and on watershed 4 by a factor of 2.58.

Figures 13 and 14 (Appendix VII) illustrate the preceding statements (1-6). It is clear that, on the average, the nutrient amounts from both needles and frass deposited on both watersheds went up in 1973. Increases on watershed 4 were larger in every instance than those observed for watershed 1.

Table 29 reflects the effects of increased DFTM larval populations by contrasting mean frass and needle weights deposited. These data are split according to the trap data usable for calculation of particular nutrient deposition values. Note that the results are weighted upward where some trap data is missing since the traps responsible for the values used are those with higher than the watershed average amounts of deposited materials.

Obvious t here is the greater increase in DFTM effects on watershed 4. Not so obvious from the means themselves is the differential effect between needles and frass. Increases from 1972 values were calculated to reflect this. They show that frass increases were greater than needle increases on both watersheds, but the effect was again larger on watershed 4. Except for the frass increases on watershed 4, the factors of increase appear to be only slightly affected by the difference in the number of traps used in calculating increases in the means. The potential influence of yearly variation in natural needle-fall on data similar to the preceding data is discussed below.

Listed in Table 30 are the percentages of the total deposition of each nutrient due to frass versus fallen-needles compared between growing seasons for each watershed. Ordering of nutrients in amounts of deposition from either frass or needles was very consistent for both years and watersheds. Calcium was highest followed by nitrogen, potassium, magnesium, phosphorus and sulfur.

Results of Phase 2, Objective 2:

The second objective of Phase 2 addressed tussock moth effects on trends in annual nutrient deposition. Figures 15 - 20 and Tables 43 - 44 portray the patterns observed. Data were derived from the mean values listed in Tables 31 - 42.

The figures show that all nutrients in frass follow the same general deposition pattern. With one exception the amounts of each of the six nutrients distributed in frass increased from collection III to collection IV and decreased from IV to V. The sole exception is potassium which showed a slight decrease in amount deposited in collection IV on watershed 1 (Figure 17).

The fallen-needle data for all nutrients except potassium show generally no marked increases or decreases in the amounts deposited between collections III and IV, but display a substantial jump from IV to V. Potassium was the only nutrient that demonstrated more than a slight decrease between collections III and IV on watershed 1.

The graphs show the total deposition (frass + needles) of each nutrient to vary as follows: Calcium shows a steady increase from collection III through VI on both watersheds. Magnesium amounts increased slightly from III to IV, then increased more rapidly from IV to VI. Potassium is inconsistent. Watershed 1 displays a decrease in potassium from III to IV, no change from IV to V and an increase from V to VI. Watershed 4 shows an increase in the amount of potassium

deposited in collection IV, a decrease in V and an increase from V to VI. Phosphorus follows deposition patterns that are quite similar to potassium. Sulfur and nitrogen both show a steady increasing trend from III through VI.

As seen in Tables 43 and 44 the percent of nutrients deposited in frass, based on the total frass and needle nutrients deposited, increased on watershed 1 by roughly 10 to 15 percent for all nutrients from collection III to IV. The same comparison for watershed 4 reveals a 20-35 percent increase for all the nutrients. From collection IV to V the amounts deposited in frass decrease significantly on a percentage basis on both watersheds.

Tables 43 and 44 also show that the percentage of nutrients deposited in frass through the summer and early fall (Σ III, IV and V) ran between 25 and 35 percent on watershed 1 and between 34 and 49 percent on watershed 4. For the winter period the contribution from frass dropped to less than one percent. The figure for VI, however, may somewhat misrepresent the true picture since leaching and decomposition of needles and frass likely occurred through the winter period and during the subsequent spring thaw. One might also expect that decomposition of the needles occurs at a slower rate than frass due to a smaller surface area to weight ratio for the needles.

As seen from Figures 15 - 20 all nutrients deposited in frass followed the same general pattern of seasonal variation. The quantities of the trapped material changed substantially from collection to collection while the concentrations held fairly constant (Tables 17-20). Quantities of trapped frass varied with each collection as the DFTM larval population and age developed.

The fallen-needle data contrasts with the frass results by showing relatively little change in amounts deposited from III to IV whereas needle deposition increased sharply in period V. Period V was past the time span of larval activity

and we would expect some delayed impact of feeding damage on needles which would ordinarily drop with normal needlefall. We have no way to separate the two.

Phase 2, Discussion:

We attribute the differences in nutrient deposition primarily to larval population differences between study years. A lighter population of DFTM in 1972 (actual population data is currently unavailable) would correspond to the smaller weights of frass collected. The increase in weights of frass and fallen needles in 1973 is attributed to a larger population dropping more frass and "clipping" more needles. The more pronounced increases in frass and amounts of nutrients deposited on watershed 4 as compared to watershed 1 is largely due to a greater increase in DFTM population on watershed 4 from 1972 to 1973.

The increased nutrient deposition due to the DFTM between periods I (1972) and III, IV and V (1973) are considerable, particularly in view of the fact that populations in both watersheds were relatively low. Frass represented a lower percentage of the total needle plus frass deposition, however, the data indicate that part of the needle drop contribution in likely relatable to clipping by larvae (note the greater increases in needlefall associated with greater increases in frass deposition when contrasting watershed 1 versus watershed 4 between growing seasons). Normal yearly differences in stand needlefall, if they were present, cannot be separated from increased clipping effects by larvae. This confounding effect is but one of several encountered in this work.

The differentials in nutrient increases from 1972 to 1973 are likely partially due to differences in the number of traps and their associated weighting factors. There are possible differences in weathering influences between years due to the fact that the 1972 period represents a single collection as opposed to multiple collections in 1973. The comparatively high change in potassium

may reflect this and is likely the element most subject to this effect (particularly in frass). However, it is our opinion that because a reasonable consistency in the data exists among the other five elements, most of the differences in nutrient deposition should be attributed to DFTM activity.

The most reliable data is associated with nitrogen due to the larger number of trap analyses obtained. Using nitrogen as a barometer shows that the within-season impact of DFTM, considering the frass source alone, represents a significant addition to nutrient deposition from needles. This is particularly true on watershed 4 where about 34 percent of the nitrogen from frass and needles occurred in frass in 1973 contrasted with 6 percent in 1972 (Table 30).

Percentages of nutrients as frass ranged from 2% to 14% in 1972 compared to a range of 21% to 40% in 1973. Assuming that the DFTM nutrient cycling effects are solely related to frass, of course, ignores any needle clipping influence and thus one could view these percentages as being conservative. Although some of the percentage data may be weighted upward by the limited numbers of traps involved, there is a considerable degree of similarity with the values for nitrogen.

Interestingly, an increase in the weighted mean <u>concentrations</u> of all nutrients <u>in frass</u> collected from each trap listed in Tables 17-20 from 1972 to 1973 was observed, although in a few instances the increase was not large. For the <u>fallen needles</u> most increased, but some decreases were noted. In spite of concentration decreases the overall <u>amounts</u> of nutrients deposited increased from 1972 to 1973 in every category, and where decreases in concentration did occur, the quantities of material deposited made up the difference.

A shortage of frass affected seasonal comparisons considered under objective 2 as well. We have <u>not</u> taken the liberty of assuming average values of concen-

trations to substitute for "zeros" in frass deposition to frass-nutrient deposition in period VI even though the amounts would be small. Data for nitrogen is the most complete.

Dynamics in frass-nutrient and frass weight deposition patterns largely reflect fluctuations in numbers and the degree of larval activity on the two watersheds. The peak influence was probably delayed somewhat on High Ridge compared to that at the Phase 1 site because of lower temperatures at the former.

A rather high percentage (Tables 43 and 44) of the two nutrient deposition sources was contributed by frass. This is to some extent surprising because the area in question sustained comparatively light damage. These values discount probable increased needle drop due to the larval feeding, hence values could be higher yet if this source could be singled out. Higher frass-nutrient deposition percentages in periods III - V diminish when the 12 month period IV - VI is considered.

<u>Conclusions</u>:

We are currently continuing data interpretations which will be forthcoming in manuscript form. Numerous uncontrolled variables were present which preclude interpretation at this time other than obvious differences already noted.

<u>Recommendations</u>:

Future endeavors with sampling and analyses of nutrients paralleling or extending the exploratory work described in this paper should ~~e~~incorporate several changes and additions to the procedures.

1. Careful differentiation of frass types should be carried out. This is especially important at lower DFTM larval population levels. The use of a dissecting scope and reference samples for appropriate species would substantially aid this effort.

2. The use of control plots is essential. Circumstances were such that no useful control plot was included in the work described in this study. Interpretation of much of the data is precluded by the lack of comparison between an uninfested-unsprayed and infested-unsprayed study units. Highly similar forest stands are inherently required.

3. The frequency of sampling should be increased to at least once per week. Two week or four week intervals tend to mask intermediate fluctuations in nutrient levels inherent in a rapidly developing larval population. Weather effects would be minimized by more frequent sampling.

4. Many aspects of the study would be simplified if the DFTM population was larger. Phase 1 was somewhat hampered by the relatively low population level encountered. A population at the peak of larval development (instar 2 or 3) of 100 larvae per 1000 square inches would be more workable for the dimensions of the traps used in this study.

5. Trap size should be varied to suit the magnitude of the insect population and a fine mesh screen is needed. A portion of frass can pass through ordinary window screen.

6. Field sampling should be coordinated with laboratory feeding trials or otherwise adapted so that the amount of foliage consumed compared to frass produced on a per insect basis can be monitored.

7. On site weather data recorded during field sampling periods may aid interpretation of the results.

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APPENDIX I

COLLECTION TIME TABLE

Collection	Dates (1974)	Collection Period (days)	Total (days)
I	June 13 - June 27	14	14
II	June 27 - July 11	14	28
III	July 11 - July 25	14	42
IV	July 25 - August 8	14	56
V	August 8 - August 22	14	70
VI	August 22 - September 5	14	84
VII	September 5 - September 21	16	100
VIII	September 21 - October 3	12	112
IX	October 3 - October 19	16	128
X	October 19 - October 31	12	140
XI	October 31 - November 16	16	156

APPENDIX II

Tree Description

Tree # (a)	Diameter (inches)	Height (feet)	Age
DF - 17	7.2	28	37
DF - 19	5.6	27	23
DF - 20	8.4	35	28
DF - 21	7.3	32	33
GF - 18	6.4	39	20
GF - 22	6.6	33	57
GF - 23	7.4	38	43
GF - 24	6.2	22	49

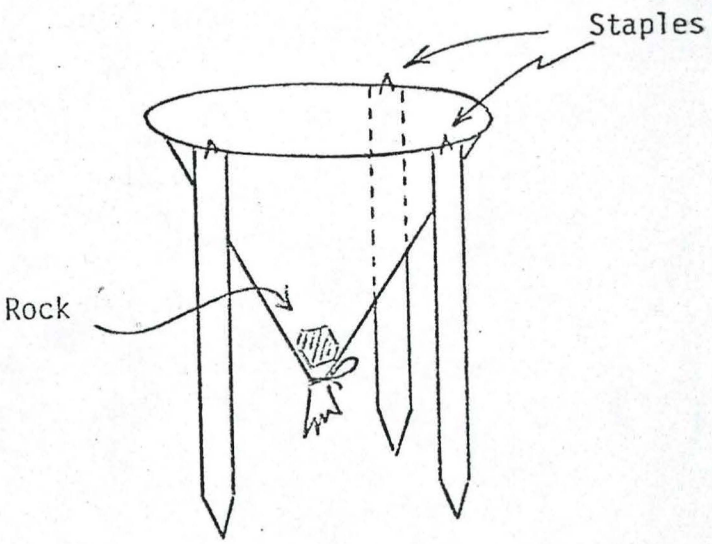
(a) Douglas-fir (DF). Grand fir (GF).

APPENDIX III

Phase I Trap Description

Conical traps made of cotton muslin and supported by a wire hoop and three wooden stakes were placed under the trees so that the mouth of the trap was directly under the tips of the branches at mid-crown. The stakes, made from .75" x 1.5" pine to a length of 20 to 25 inches, were driven 4 to 6 inches into the soil in a triangular pattern so as to provide adequate support to the 19.2 inch diameter trap opening. The wire hoop, inserted into the folded and sewn-down rim of the mulsin cone, was stapled to the tops of the wooden stakes (Figure 1). An opening at the bottom of the cone was tied together with twine and weighted with a small rock at the outset of each sample collection period. The bottom of the trap cleared the ground by three to four inches.

FIGURE 1



APPENDIX IV

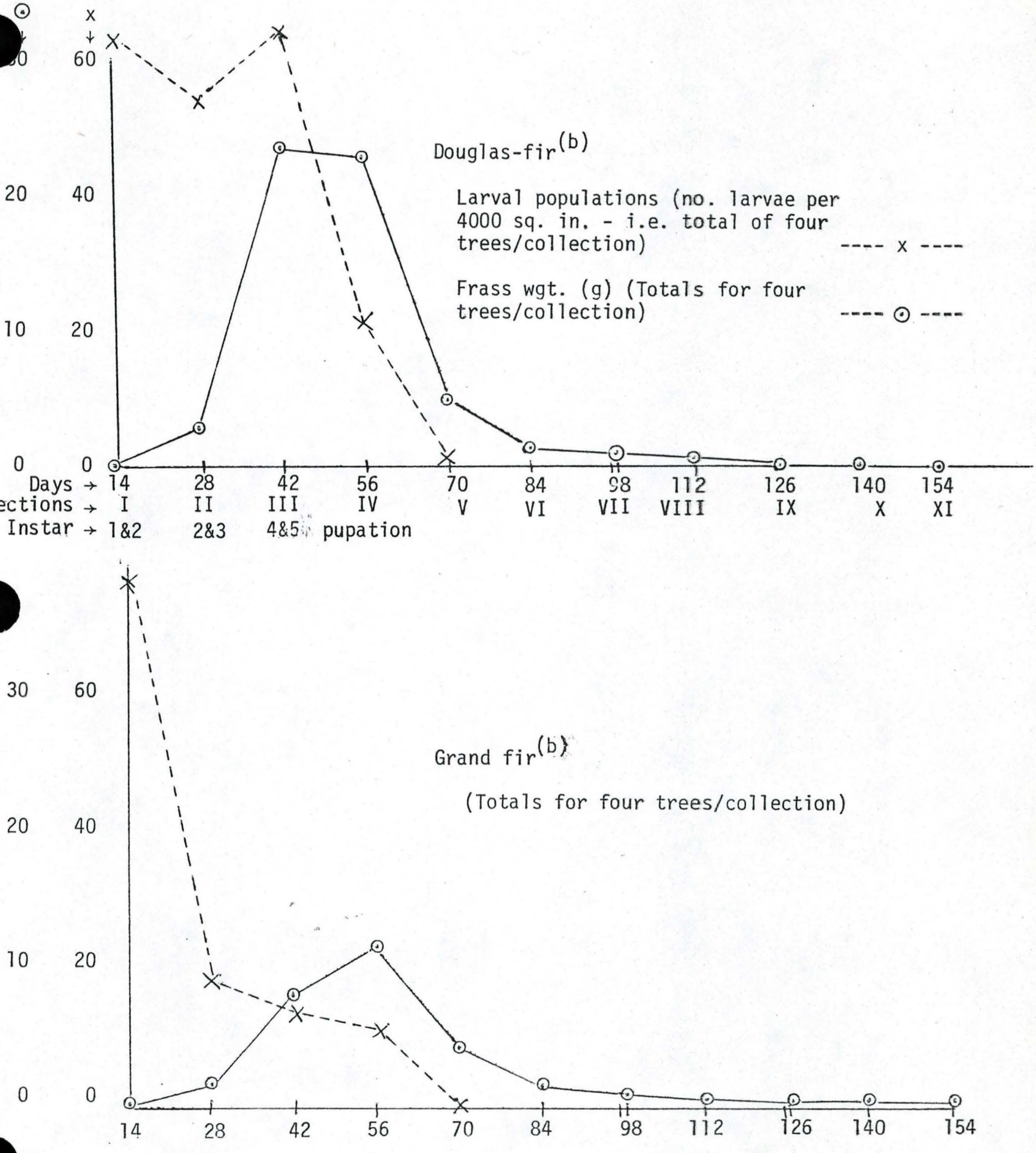
Population Data of Simerson Springs

Larval Density (number of larvae per 1000 sq. in.)

Tree	6-29-74	7-11-74	7-26-74	8-8-74	8-22-74	Total
	Date of Measurement					
DF - 17	27.1	26.3	18.2	2.2	0	73.8
DF - 19	7.9	3.0	11.6	5.9	0	28.4
DF - 20	17.1	6.7	23.6	6.8	1.7	55.9
DF - 21	10.3	18.0	10.5	6.1	0	44.9
Total	62.4	54.0	63.9	21.0	1.7	
GF - 18	30.0	15.8	5.6	7.7	0	59.1
GF - 22	19.7	0	4.0	1.5	0	25.2
GF - 23	22.7	2.6	3.8	0	0	29.1
GF - 24	5.0	0	0	2.45	0	7.45
Total	77.4	18.4	13.4	11.65	0	
Stage or Instar:	1 & 2	2 & 3	4 & 5	Beginning Pupation	Pupation ∿ complete	

APPENDIX V

Frass Yield vs Larval Density per Tree Species per Collection[a]



(a) Campbell, Progress Report: "Exploratory Study of Tussock Moth Frass and Litter Production Under Douglas-fir and Grand Fir Trees", USDA, Mar. 21, 1975.

(b) The first three points on the graphs showing the frass yield, ⊙ (collections I - III) are single trap values x 3. Points for collections IV - XI are the actual triple-trap values.

APPENDIX VI

CHEMICAL ANALYSES

1. Total nitrogen: A 50 to 100mg portion of sample material was predigested with 5ml salicylic acid - H_2SO_4 - $SeOCl_2$ mixture overnight. Approximately 0.4g sodium thiosulfate ($Na_2S_2O_3$) was added and the mixture was heated at 100°C until frothing ceased. The solution was cooled, 1.5g potassium sulfate (K_2SO_4) was added and the mixture was digested at 310-320°C until colorless. The digest was cooled, diluted to 50ml with distilled water and mixed thoroughly. Aliquots of 1ml were diluted to 23ml. A 2ml portion of Nessler reagent[4] was added, mixed and the absorbance of the sample was recorded from a spectrophotometer at 440nm.

2. Total sulfur: A 0.3 gram portion of dried, ground sample material was weighed into a 50ml NPN digestion tube. Five milliliters of concentrated HNO_3 was added. The sample was allowed to soak in the HNO_3 until thoroughly moist. A 2.0ml portion of concentrated (70-72%) $HClO_4$ was added and the tube was placed into a digestion block at, or less than, 100°C. (See Figure 1). The temperature of the block was increased to 240-260°C. After the majority of the HNO_3 had boiled off, a buret funnel was inserted into the neck of each NPN tube to serve the dual purpose of reflux condenser and bumping baffle for escaping $HClO_4$. The

4 Nessler Reagent (an alkaline solution of tetraiodomercurate (II), $HgI_4^{=}$) was purchased from Anderson Laboratories, Inc. 1901 West Vickery, Fort Worth, Texas 76101.

tubes were heated at 240-260°C for about 30 minutes beyond the initial appearance of dense white $HClO_4$ vapors. When the liquid in the tubes had decreased in volume to about 1ml the tubes were cooled. The funnels were rinsed into the tubes with 15-20mls deionized water. A 5ml portion of 6 N HCl + 10ppm S (K_2SO_4) was added. Then the samples were diluted to 50.0ml, shaken thoroughly and filtered by gravity into storage bottles. (The filtered solution is referred to hereafter as "the perchloric acid digest".)

A 10ml aliquot of the $HClO_4$ digest solution was pipetted into a 50ml beaker. Four drops of 0.5% gum arabic (Acacia) was added and the solution was swirled. A 0.5g portion of sieved (< 1mm, > 1/2mm) $BaCl_2$ was added and allowed to stand briefly. After 1 minute passed the suspension was swirled intermittently for 1 minute so that the $BaCl_2$ just dissolved. It was then allowed to stand for an additional 3 minutes. The suspension was swirled and transferred to a spectrophotometer cuvette. The optical density at 420nm was recorded and compared to a previously determined standard curve.

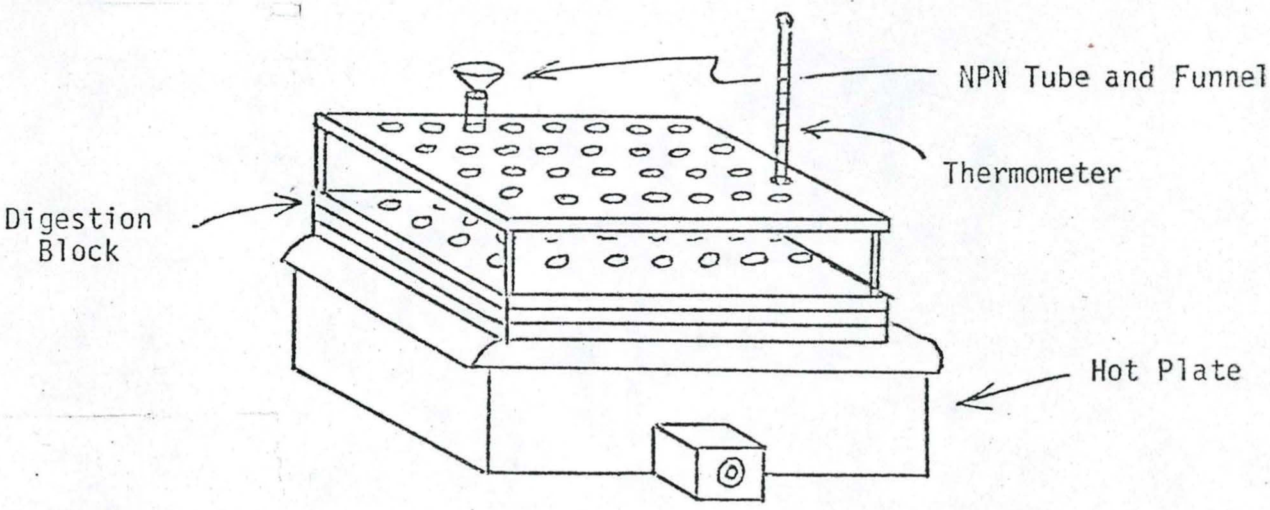


Figure 2

3. Total phosphorus: A 5ml portion of the original perchloric acid digest (see total sulfur discussion) was pipetted into a 25ml volumetric flask. Five milliliters of Barton's Reagent[5] was added. The solution was diluted to 25ml. After thorough mixing the solution was allowed to stand for 1 hour. A spectrophotometer reading was recorded for 400nm if the P concentration was less than 400ppm. If the P concentration was higher than 400ppm the spectrophotometer reading was taken at 420nm.

4. Total potassium: Potassium was analyzed with a Perkin Elmer (Model 305B) Atomic Absorption Spectrophotometer using a portion of the solution remaining from the phosphorus (Barton's reagent) determination (see above).

5 and 6. Calcium and Magnesium: A 1ml aliquot of the perchloric acid digest (see foregoing total sulfur procedure) was diluted to 26ml. Five ml of 2.5% (w/v) strontium chloride-hexahydrate ($SrCl_2 \cdot 6H_2O$) was added. The solution was thoroughly mixed and set aside to stand overnight. Ca and Mg was then determined using the Perkin Elmer (Model 305B) Atomic Absorption Spectrophotometer.

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5 Barton's Reagent. Solution 1: 25g ammonium molybdate dissolved in 400ml water. Solution 2: 1.25g ammonium metavanadate dissolved in 300ml boiling water, cooled, treated with 250ml conc. HNO_3, cooled again to room temperature. Solutions 1 and 2 were combined and diluted to 1 liter.

Table [illegible]ase 1)
New Foliage and Frass
Douglas-fir 17
Nutrient Concentration in $\mu g/g$ tissue

	Ca		Mg		K		P		S		N	
Collection	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass
I	3,049		1,084		7,927		2,435		986		16,089	
II	3,711		1,013		7,078		1,557		692		11,571	10,334
III	3,715	4,337	941	912	7,043	8,282	1,414	1,226	631	551	11,324	6,274
IV	4,343	10,664	1,037	844	6,746	3,726	1,461	802	638	711	10,545	7,204
V	5,083	11,048	1,063	1,000	6,359	7,213	1,436	1,347	626	837	11,060	9,094
VI	7,767		849		5,797		1,252		680		11,502	8,469
VII	5,047		1,047		6,243		1,386		619		10,755	8,065
VIII	4,953		1,133		7,086		1,473		646		10,641	7,807
IX	4,571		1,066		7,228		1,465		760		10,482	
X	4,307		1,079		7,884		1,550		590		10,851	
XI	4,581		1,140		6,699		1,521		649		10,659	
Σ	51,127	26,049	11,452	2,756	76,090	19,221	16,950	3,375	7,517	2,099	125,479	57,247
$\bar{x}$	4,650	8,683	1,041	919	6,917	6,407	1,541	1,125	683	700	11,407	8,178
s	1,212	3,769	84	78	650	2,383	308	286	110	143	1,599	1,310

Table 2 (Phase 1)
New Foliage and Frass
Douglas-fir 19
Nutrient Concentration in μg/g tissue

Collection	Ca 1974 Foliage	Ca Frass	Mg 1974 Foliage	Mg Frass	K 1974 Foliage	K Frass	P 1974 Foliage	P Frass	S 1974 Foliage	S Frass	N 1974 Foliage	N Frass
I	2,495		1,064		8,749		2,473		1,078		19,002	
II	2,714		1,086		7,399		1,794		773		13,164	8,008
III	4,649	4,194	1,222	1,016	6,907	7,877	1,200	968	535	508	11,047	5,620
IV	4,578	13,659	1,370	972	7,564	4,321	1,502	738	1,123	737	11,074	6,878
V	4,940	14,447	1,234	1,090	6,492	8,051	1,068	1,501	614	844	12,185	8,674
VI	6,404		1,520		6,907		1,081		664		11,625	9,086
VII	6,026		1,586		6,907		1,239		645		10,242	7,897
VIII	6,662		1,609		7,919		1,483		690		11,197	7,830
IX	7,120		1,343		7,466		1,502		697		10,234	
X	6,670		1,644		7,884		1,668		849		11,672	
XI	5,594		1,574		7,339		1,114		624		10,182	
Σ	57,852	32,300	15,252	3,078	81,533	20,249	16,124	3,207	8,292	2,089	131,624	53,993
$\overline{X}$	5,259	10,767	1,387	1,026	7,412	6,750	1,466	1,069	754	696	11,966	7,713
s	1,565	5,706	213	60	625	2,105	415	391	190	172	2,502	1,156

Table 3 [illegible]se 1)
New Foliage and Frass
Douglas-fir 20
Nutrient Concentration in $\mu g/g$ tissue

Collection	Ca		Mg		K		P		S		N	
	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass
I	1,850		967		8,694		2,615		1,309		19,192	
II	4,722		1,169		6,467		1,482		693		12,268	9,616
III	3,930	4,043	1,157	1,117	7,184	7,908	1,395	1,185	662	747	10,225	6,894
IV	4,060	11,385	1,230	1,128	5,986	3,521	1,327	915	717	687	11,064	7,588
V	3,823	11,197	1,120	1,539	6,540	7,558	1,287	1,905	611	1,163	10,458	10,326
VI	4,733		1,343		6,056		1,367		735		10,626	9,075
VII	4,350		1,407		6,333		1,486		687		8,487	6,514
VIII	5,259		1,468		6,242		1,597		801		10,816	
IX	4,314		1,515		6,416		1,714		899		10,537	
X	4,184		1,462		6,261		1,649		755		9,985	
XI	4,562		1,398		6,124		1,549		771		10,423	
Σ	45,787	26,625	14,236	3,784	72,303	18,987	17,468	4,005	8,640	2,597	124,081	50,013
$\overline{x}$	4,162	8,875	1,294	1,261	6,573	6,329	1,588	1,335	785	866	11,280	8,336
s	871	4,186	176	241	774	2,438	366	512	190	259	2,772	1,556

Table 4 (Phase 1)
New Foliage and Frass
Douglas-fir 21
Nutrient Concentration in μg/g tissue

	Ca		Mg		K		P		S		N	
Collection	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass
I	2,420		987		7,838		2,728		1,488		19,062	
II	3,653		950		5,978		1,675		802		12,423	9,150
III	3,853	3,993	987	928	5,614	5,580	1,422	1,171	742	874	11,717	5,572
IV	3,764	8,083	1,014	901	5,554	4,030	1,340	843	771	703	10,560	6,089
V	3,883	9,544	950	1,060	4,811	6,753	1,244	1,318	690	852	11,583	7,096
VI	3,752		950		5,531		1,318		759		10,666	6,570
VII	4,382		1,020		4,779		1,338		781		10,640	6,862
VIII	4,680		1,097		5,459		1,144		745		10,020	6,449
IX	4,300		1,040		5,170		1,398		772		10,409	
X	4,525		1,047		5,081		1,449		788		10,163	
XI	3,927		983		5,116		1,330		729		10,163	
Σ	43,139	21,620	11,025	2,889	60,931	16,363	16,386	3,332	9,067	2,429	127,406	47,788
$\bar{x}$	3,922	7,207	1,002	963	5,539	5,454	1,490	1,111	824	810	11,582	6,827
s	607	2,877	47	85	844	1,366	432	243	222	93	2,594	1,140

Table 5 ([illegible]se 1)
New Foliage and Frass
Grand fir 18
Nutrient Concentration in μg/g tissue

Collection	Ca 1974 Foliage	Ca Frass	Mg 1974 Foliage	Mg Frass	K 1974 Foliage	K Frass	P 1974 Foliage	P Frass	S 1974 Foliage	S Frass	N 1974 Foliage	N Frass
I	3,868		1,136		9,936		2,968		980		17,231	
II	5,548		1,070		7,475		1,888		840		13,749	8,774
III	7,027	8,466	1,252	1,209	6,976	7,635	1,515	2,235	684	968	11,033	7,640
IV	7,312	14,308	866	1,271	6,654	4,311	1,512	994	722	683	11,353	7,140
V	6,714	13,977	967	1,637	5,758	6,841	1,386	1,397	685	847	12,876	9,151
VI	9,888		1,449		5,651		1,502		822		13,492	7,719
VII	9,253		1,598		6,628		1,602		735		12,206	7,389
VIII	8,212		1,374		6,565		1,626		683		11,055	6,370
IX	8,857		1,585		6,659		1,679		741		11,445	
X	9,444		1,669		6,565		1,547		692		10,788	
XI	7,525		1,420		6,535		1,527		714		10,711	
Σ	83,648	36,751	14,386	4,117	75,402	18,787	18,752	4,626	8,298	2,498	135,939	54,183
$\overline{x}$	7,604	12,250	1,308	1,372	6,855	6,262	1,705	1,542	754	833	12,358	7,740
s	1,807	3,282	270	231	1,138	1,736	438	633	92	143	1,942	951

Table 6 (Phase 1)
New Foliage and Frass
Grand fir 22
Nutrient Concentration $\mu g/g$ tissue

	Ca		Mg		K		P		S		N	
Collection	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass
I	5,526		1,248		8,939		2,997		1,166		17,278	
II	8,699		1,243		7,787		2,058		929		13,869	7,920
III	12,409	13,588	1,305	1,495	6,096	7,850	1,568	1,664	750	1,157	12,450	8,676
IV	15,670	20,320	1,653	1,335	6,540	4,805	1,708	1,036	832	692	11,834	8,049
V	13,518	20,997	1,401	1,923	6,839	9,678	1,387	1,775	670	994	11,205	9,638
VI	14,764		1,425		6,036		1,346		781		11,512	7,546
VII	17,893		2,054		7,372		1,696		886		10,312	7,322
VIII	17,727		2,056		8,279		1,835		946		11,487	
IX	15,659		1,735		8,474		1,807		842		12,365	
X	16,664		1,874		8,079		2,027		951		12,805	
XI	14,057		1,619		6,975		1,680		910		13,001	
Σ	152,586	54,905	17,613	4,753	81,416	22,333	20,109	4,475	9,663	2,843	138,118	49,151
$\bar{x}$	13,871	18,302	1,601	1,584	7,401	7,444	1,828	1,492	878	948	12,556	8,192
s	3,805	4,096	303	304	985	2,462	448	399	130	236	1,842	848

Table 7 (Phase 1)
New Foliage and Frass
Grand fir 23
Nutrient Concentration μg/g tissue

Collection	Ca 1974 Foliage	Ca Frass	Mg 1974 Foliage	Mg Frass	K 1974 Foliage	K Frass	P 1974 Foliage	P Frass	S 1974 Foliage	S Frass	N 1974 Foliage	N Frass
I	4,234		1,053		10,654		2,649		1,252		15,440	
II	6,903		1,043		8,151		1,619		841		11,278	7,809
III	10,761	8,478	1,165	1,124	7,162	9,040	1,501	1,213	724	765	10,746	7,014
IV	10,725	16,248	1,279	1,178	7,138	6,446	1,392	903	818	698	10,625	6,554
V	10,927	17,184	1,201	1,233	6,064	8,420	1,329	1,078	709	831	10,906	7,830
VI	11,947		1,240		6,953		1,303		630		10,938	8,139
VII	9,823		1,531		8,880		2,086		924		12,475	7,955
VIII	12,467		1,520		8,248		1,724		890		11,339	6,570
IX	12,850		1,567		7,822		1,803		945		11,216	
X	11,037		1,260		8,531		1,716		954		10,423	
XI	11,117		1,490		7,564		1,482		908		10,995	
Σ	112,791	41,910	14,349	3,535	87,167	23,906	18,604	3,194	9,595	2,294	126,381	51,871
$\overline{x}$	10,254	13,970	1,304	1,178	7,924	7,969	1,691	1,065	872	765	11,489	7,410
s	2,539	4,779	192	55	1,210	1,355	393	155	165	67	1,416	678

Table 8 (Phase 1)
New Foliage and Frass
Grand fir 24
Nutrient Concentration $\mu g/g$ tissue

	Ca		Mg		K		P		S		N	
Collection	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass	1974 Foliage	Frass
I	3,456		1,053		11,086		2,914		1,316		17,938	
II	5,268		993		8,206		1,926		895		13,085	8,758
III	8,097		1,208		7,908		1,896		923		13,288	8,344
IV	6,953	14,567	993	1,375	6,746	4,402	1,637	1,091	791	754	12,926	7,676
V	7,710		1,096		8,039		1,927		872		13,345	8,495
VI	8,503		1,250		7,091		1,740		861		11,770	8,221
VII	12,415		1,582		8,275		1,722		913		11,905	6,628
VIII	8,679		1,368		8,773		2,088		922		12,999	6,512
IX	10,258		1,639		8,916		2,272		938		12,733	
X	9,970		1,472		8,346		2,184		1,017		13,234	
XI	9,241		1,403		8,168		2,246		951		13,170	
Σ	90,550	14,567	14,057	1,375	91,554	4,402	22,552	1,091	10,399	754	146,393	54,634
$\bar{x}$	8,232		1,278		8,323		2,050		945		13,308	7,805
s	2,438		232		1,117		358		135		1,625	906

Tab (Phase 1)
Year-old Foliage
Douglas-fir 17
Nutrient Concentration in μg/g tissue

Collection	Ca	Mg	K	P	S	N
I						
II						
III						
IV	5,737	723	5,428	1,406	611	12,243
V	7,263	790	5,498	1,390	697	12,347
VI	7,120	743	5,078	1,144	611	10,813
VII	7,167	847	5,428	1,343	621	11,641
VIII	7,719	839	5,912	1,363	757	11,071
IX	7,787	903	6,179	1,525	706	11,289
X	7,601	886	6,004	1,528	674	10,966
XI	6,761	854	5,801	1,576	695	10,563
Σ	57,155	6,585	45,328	11,275	5,372	90,933
$\overline{X}$	7,114	823	5,666	1,409	672	11,367
S	665	65	367	138	53	656

Tab[illegible]0 (Phase 1)
Year-old Foliage
Douglas-fir 19
Nutrient Concentration in μg/g tissue

Collection	Ca	Mg	K	P	S	N
I						
II						
III						
IV	8,735	1,344	6,497	987	589	12,243
V	8,887	1,163	6,540	1,025	668	13,004
VI	9,522	1,332	6,930	1,101	810	12,418
VII	10,351	1,378	6,354	1,140	670	11,038
VIII	12,478	1,608	7,654	1,520	848	12,009
IX	11,083	1,520	6,538	1,390	706	11,209
X	11,069	1,416	7,884	1,786	878	11,924
XI	10,429	1,621	6,231	1,061	621	9,867
Σ	82,554	11,382	54,628	10,010	5,790	93,712
$\overline{X}$	10,319	1,423	6,828	1,251	724	11,714
S	1,254	154	617	285	108	978

Table 11 (Phase 1)
Year-old Foliage
Douglas-fir 20
Nutrient Concentration in μg/g tissue

Collection	Ca	Mg	K	P	S	N
I						
II						
III						
IV	7,167	1,407	4,936	1,581	929	12,653
V	7,457	1,277	5,218	1,390	870	12,890
VI	6,690	1,373	5,078	1,430	929	12,510
VII	8,267	1,510	4,653	1,232	861	12,448
VIII	9,366	1,627	4,998	1,581	998	11,885
IX	7,837	1,710	5,820	2,018	1,053	13,469
X	9,263	1,764	5,076	1,758	1,024	12,223
XI	6,861	1,360	6,118	1,825	1,033	11,628
Σ	62,908	12,028	41,897	12,815	7,697	99,706
$\overline{X}$	7,864	1,504	5,237	1,602	962	12,463
S	1,029	179	486	256	75	576

Table 12 (Phase 1)
Year-old Foliage
Douglas-fir 21
Nutrient Concentration in μg/g tissue

Collection	Ca	Mg	K	P	S	N
I						
II						
III						
IV	7,575	1,094	4,811	1,268	766	10,181
V	7,525	1,189	4,850	1,322	771	10,556
VI	6,117	1,070	4,936	1,303	716	10,309
VII	7,332	1,159	4,140	1,180	656	11,324
VIII	8,345	1,253	4,959	1,356	773	10,263
IX	7,740	1,230	4,880	1,525	772	10,454
X	8,239	1,150	4,501	1,386	732	9,909
XI	6,596	1,063	4,848	1,468	758	10,176
Σ	59,469	9,208	37,925	10,808	5,944	83,172
$\overline{X}$	7,434	1,151	4,741	1,351	743	10,396
S	760	71	281	110	41	422

Table 13 (Phase 1)
Year-old Foliage
Grand fir 18
Nutrient Concentration in μg/g tissue

Collection	Ca	Mg	K	P	S	N
I						
II						
III						
IV	8,650	1,173	5,078	1,104	706	11,307
V	8,743	1,080	4,582	1,120	668	12,311
VI	12,660	1,653	4,866	1,224	716	11,850
VII	11,013	1,523	5,044	1,571	645	10,936
VIII	10,812	1,358	4,847	1,237	684	10,499
IX	12,033	1,562	5,984	1,347	746	11,475
X	11,940	1,773	4,677	1,140	625	9,799
XI	10,093	1,369	5,513	1,283	741	10,813
Σ	85,944	11,491	40,591	10,026	5,531	88,990
$\overline{X}$	10,743	1,436	5,074	1,253	691	11,124
S	1,495	236	465	153	44	790

Table 14 (Phase 1)
Year-old Foliage
Grand fir 22
Nutrient Concentration in μg/g tissue

Collection	Ca	Mg	K	P	S	N
I						
II						
III						
IV	20,880	1,587	5,917	1,224	851	12,700
V	18,793	1,639	6,977	1,084	766	11,464
VI	18,304	1,759	7,429	1,267	872	12,693
VII	20,195	1,805	6,270	1,502	862	12,546
VIII	20,856	1,980	7,562	1,363	766	11,823
IX	19,621	1,900	8,007	1,679	1,010	13,143
X	21,854	1,817	7,512	1,623	942	13,833
XI	18,502	1,789	7,062	1,602	928	13,238
Σ	159,005	14,276	56,736	11,344	6,997	101,440
$\overline{X}$	19,876	1,784	7,092	1,418	875	12,680
S	1,286	128	699	216	85	764

Table 15 (Phase 1)
Year-old Foliage
Grand fir 23
Nutrient Concentration in µg/g tissue

Collection	Ca	Mg	K	P	S	N
I						
II						
III						
IV	14,811	1,143	7,615	1,085	666	10,666
V	15,178	1,148	7,877	1,066	773	11,693
VI	14,619	1,084	8,283	1,108	805	11,516
VII	11,987	1,311	6,769	1,522	786	12,377
VIII	15,294	1,311	8,987	1,371	903	11,025
IX	16,963	1,270	8,460	1,478	829	11,368
X	13,811	1,086	7,512	1,362	836	10,137
XI	16,851	1,344	8,052	1,318	805	11,196
Σ	119,514	9,697	63,555	10,310	6,403	89,978
$\overline{X}$	14,939	1,212	7,944	1,289	800	11,247
S	1,605	108	672	180	67	674

Tab[illegible]6 (Phase 1)
Year-old Foliage
Grand fir 24
Nutrient Concentration in μg/g tissue

Collection	Ca	Mg	K	P	S	N
I						
II						
III						
IV	10,234	1,066	6,726	1,247	782	11,842
V	10,214	1,177	7,528	1,459	728	12,689
VI	12,807	1,339	6,036	1,322	761	10,956
VII	15,625	1,348	7,115	1,347	651	11,562
VIII	13,143	1,402	7,866	1,655	897	11,976
IX	13,475	1,515	7,086	1,813	951	12,095
X	13,099	1,520	6,921	1,689	805	12,857
XI	11,821	1,334	6,424	1,689	730	11,125
Σ	100,418	10,701	55,702	12,221	6,305	95,102
$\overline{X}$	21,552	1,338	6,963	1,528	788	11,888
S	1,788	155	583	210	97	675

Figure 1

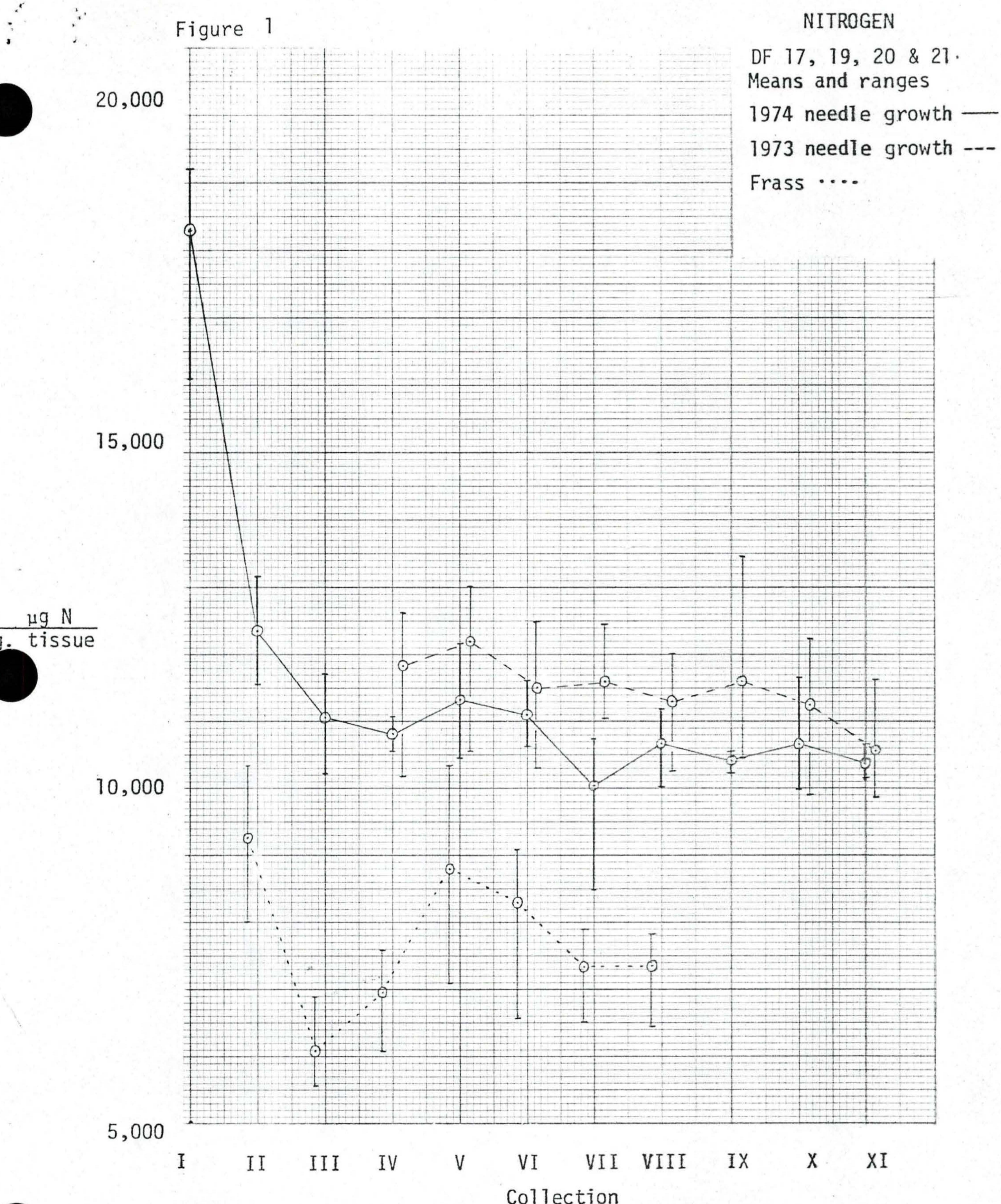

NITROGEN
DF 17, 19, 20 & 21
Means and ranges
1974 needle growth ——
1973 needle growth ---
Frass ····
20,000
15,000
10,000
5,000
μg N / g. tissue
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Collection

Figure 2

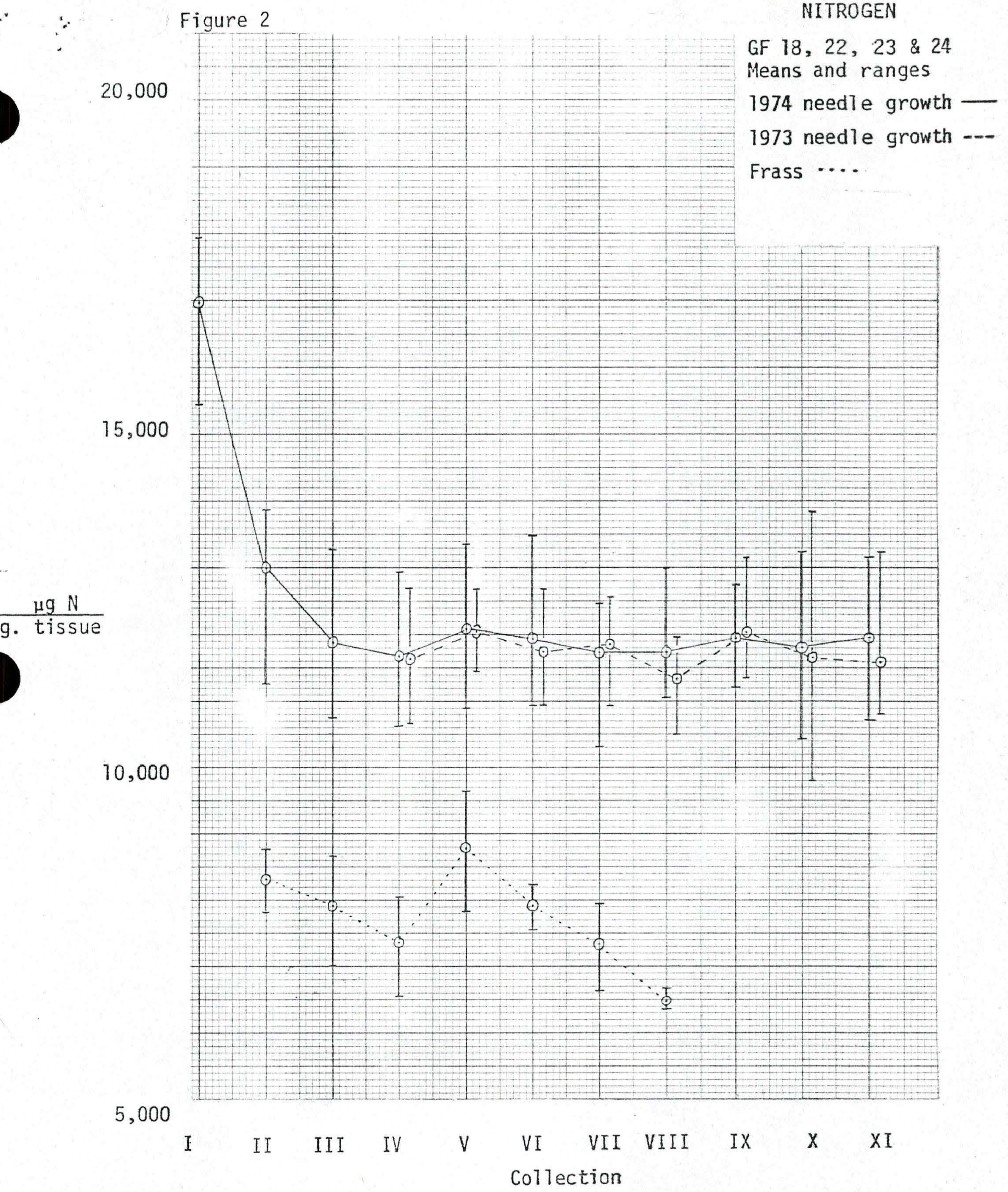

NITROGEN
GF 18, 22, 23 & 24
Means and ranges
1974 needle growth ——
1973 needle growth ---
Frass ----
20,000
15,000
10,000
5,000
µg N / g. tissue
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Collection

Figure 3

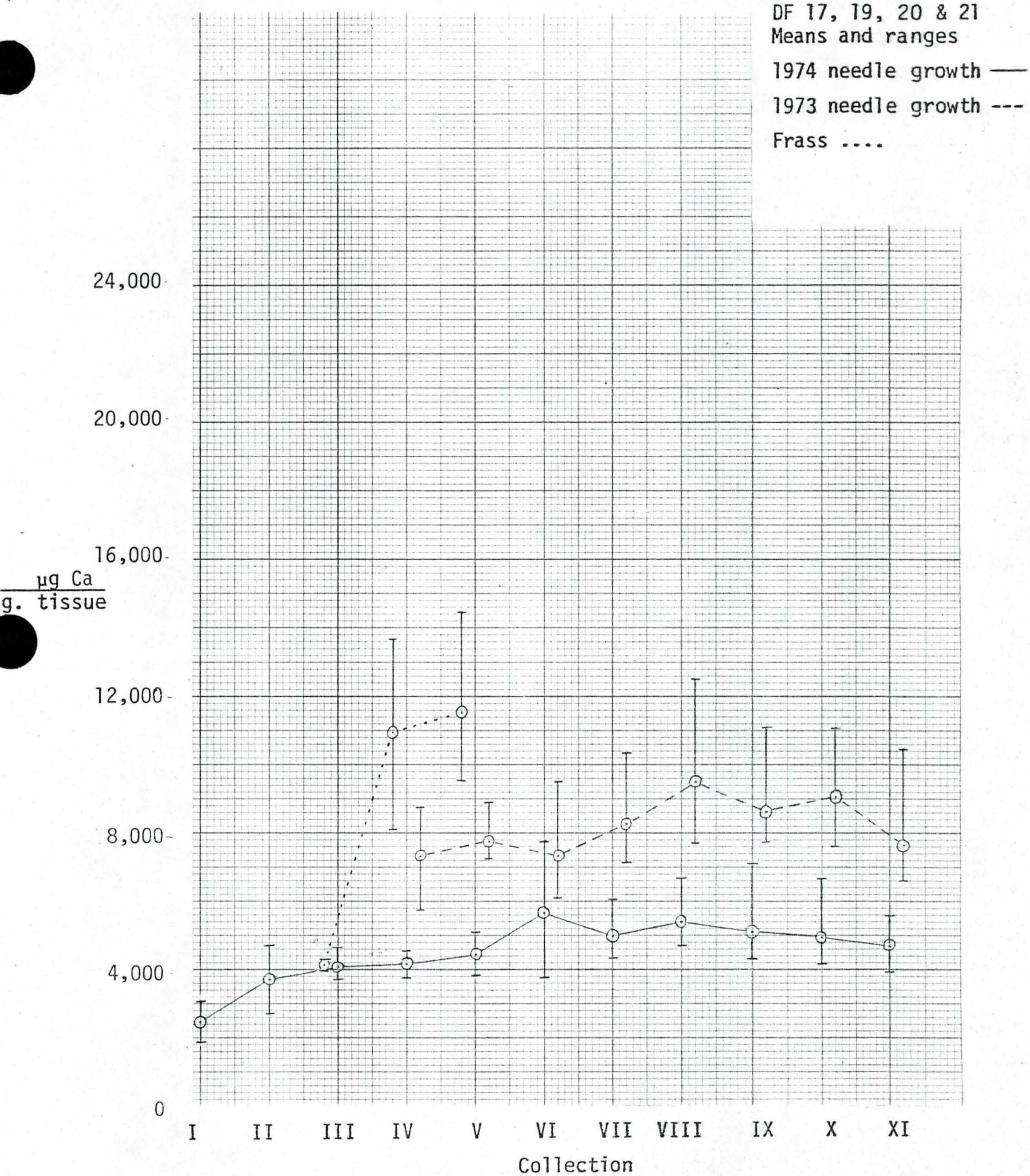
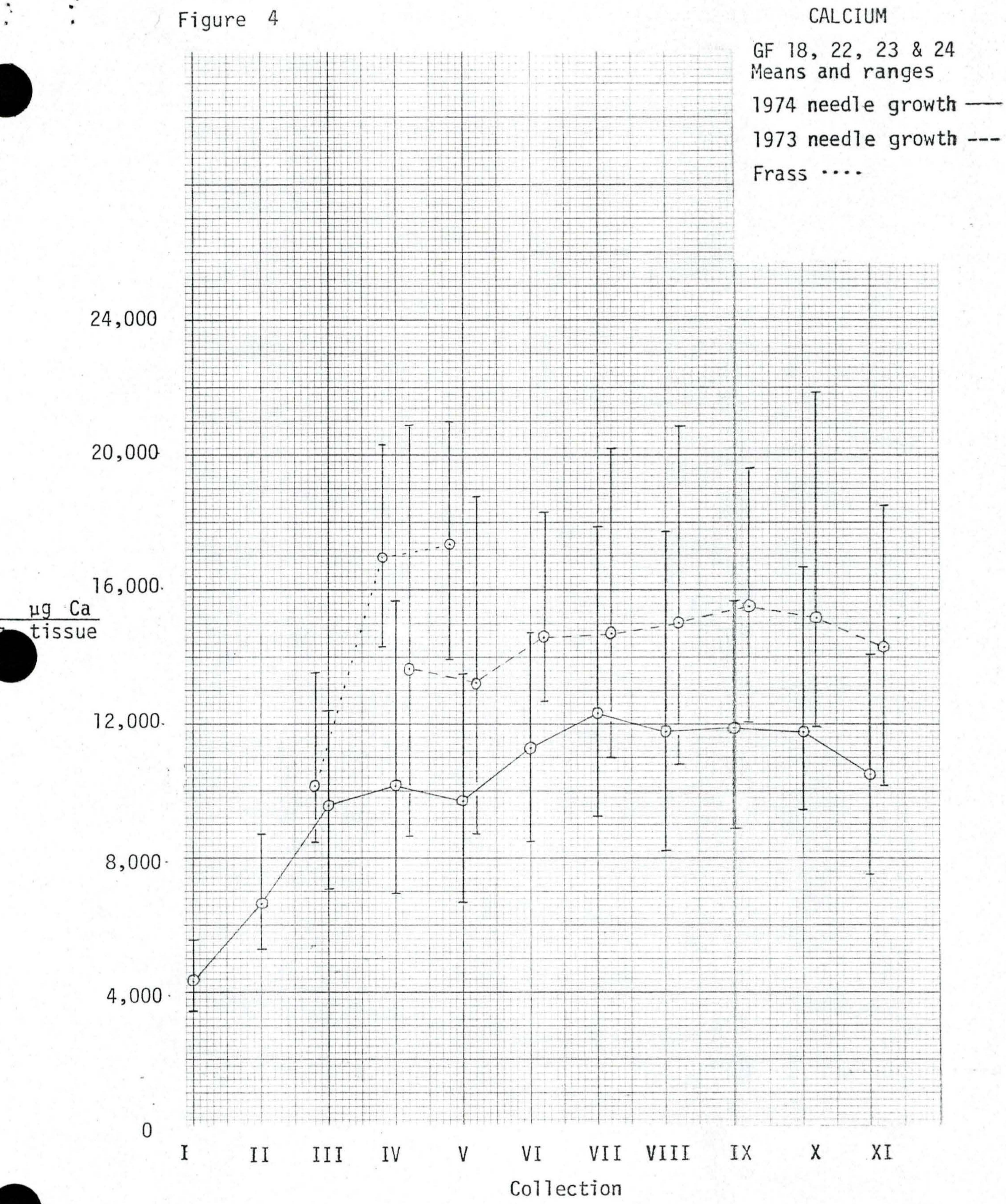

CALCIUM
DF 17, 19, 20 & 21
Means and ranges
1974 needle growth ——
1973 needle growth ---
Frass ....
24,000
20,000
16,000
μg Ca / g. tissue
12,000
8,000
4,000
0
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Collection

Figure 4



CALCIUM
GF 18, 22, 23 & 24
Means and ranges
1974 needle growth ——
1973 needle growth ---
Frass ····
24,000
20,000
16,000
12,000
8,000
4,000
0
μg Ca
tissue
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Collection

Figure 5

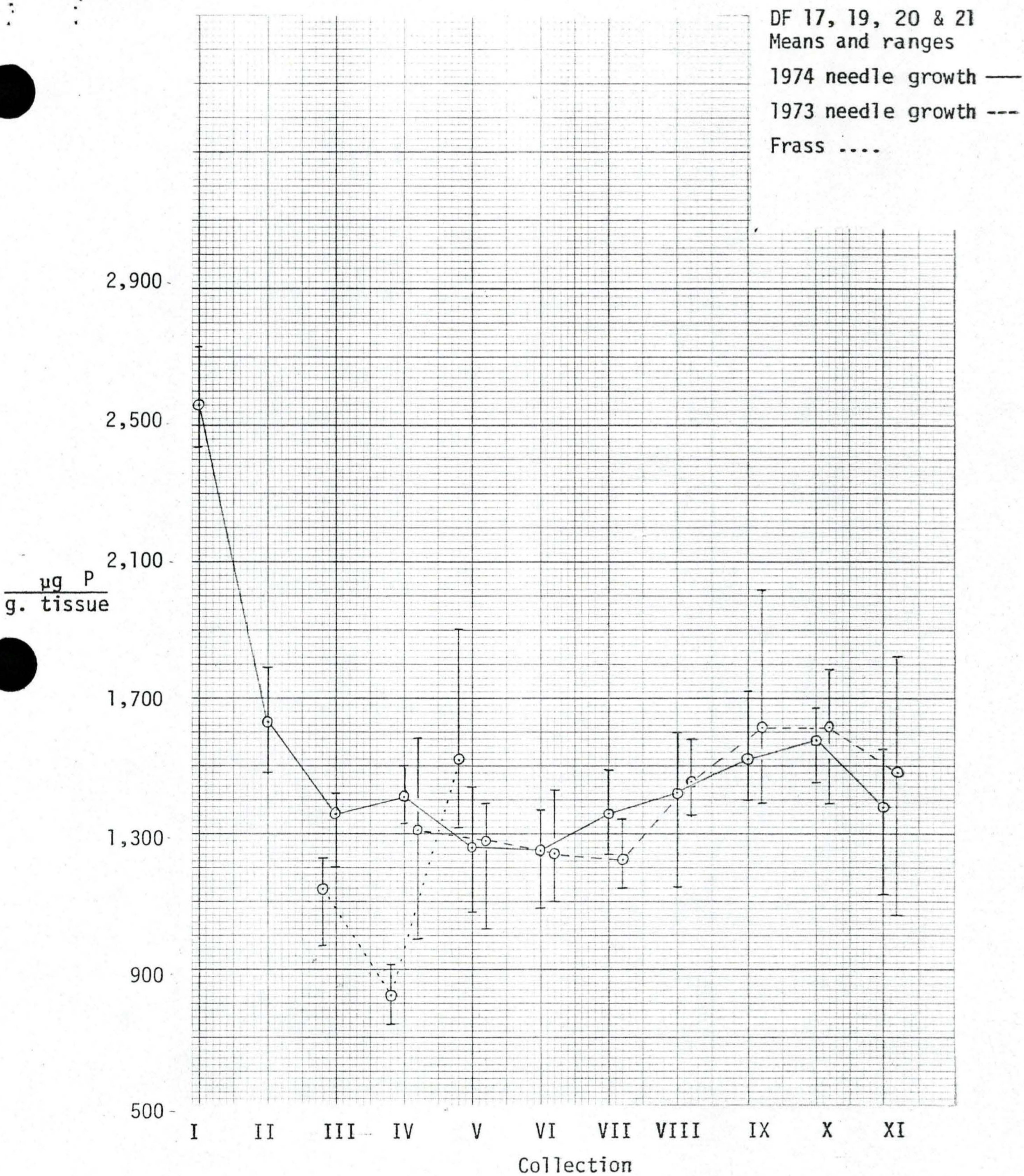

PHOSPHORUS
DF 17, 19, 20 & 21
Means and ranges
1974 needle growth ——
1973 needle growth ---
Frass ....
2,900
2,500
2,100
1,700
1,300
900
500
µg P / g. tissue
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Collection

Figure 6

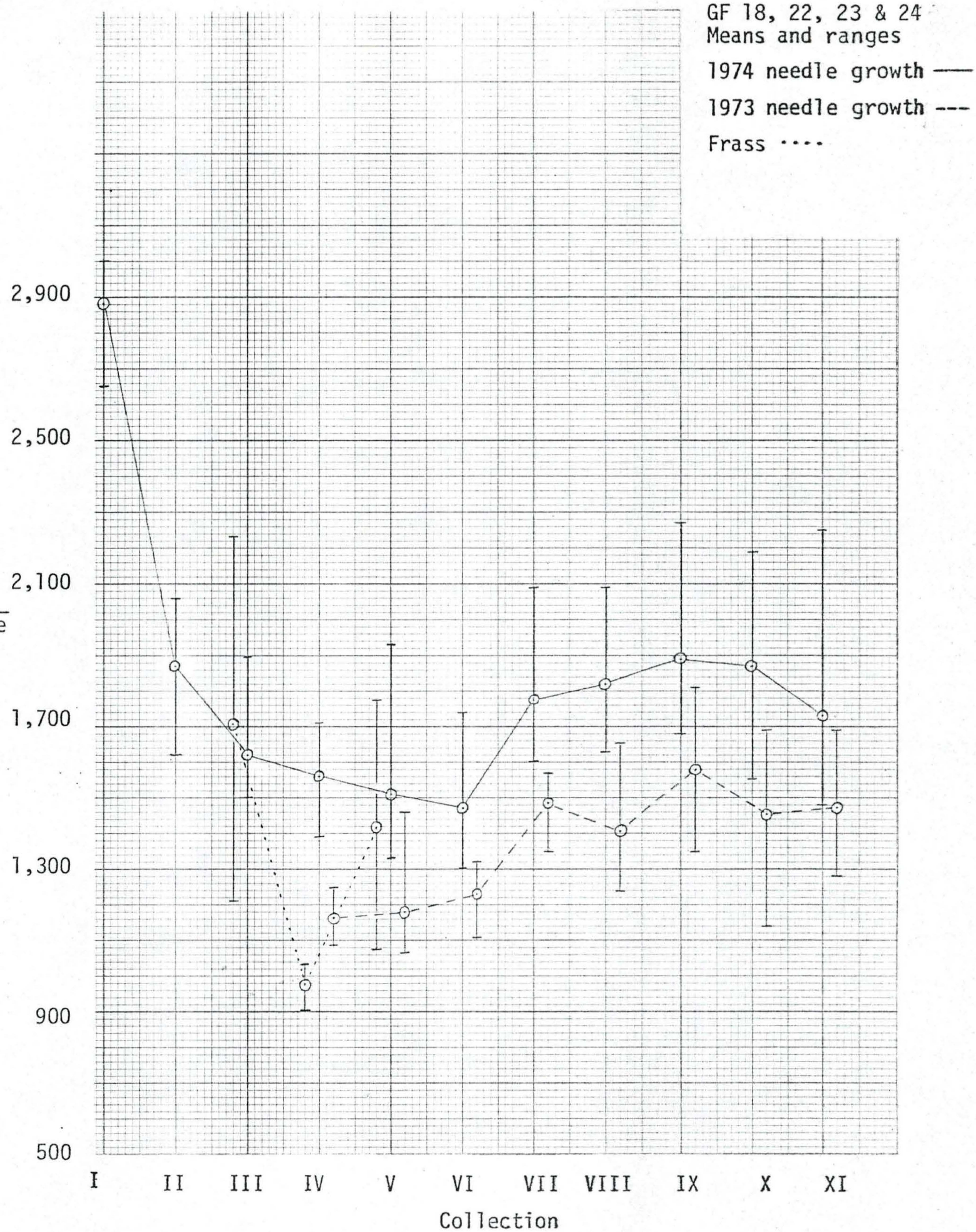
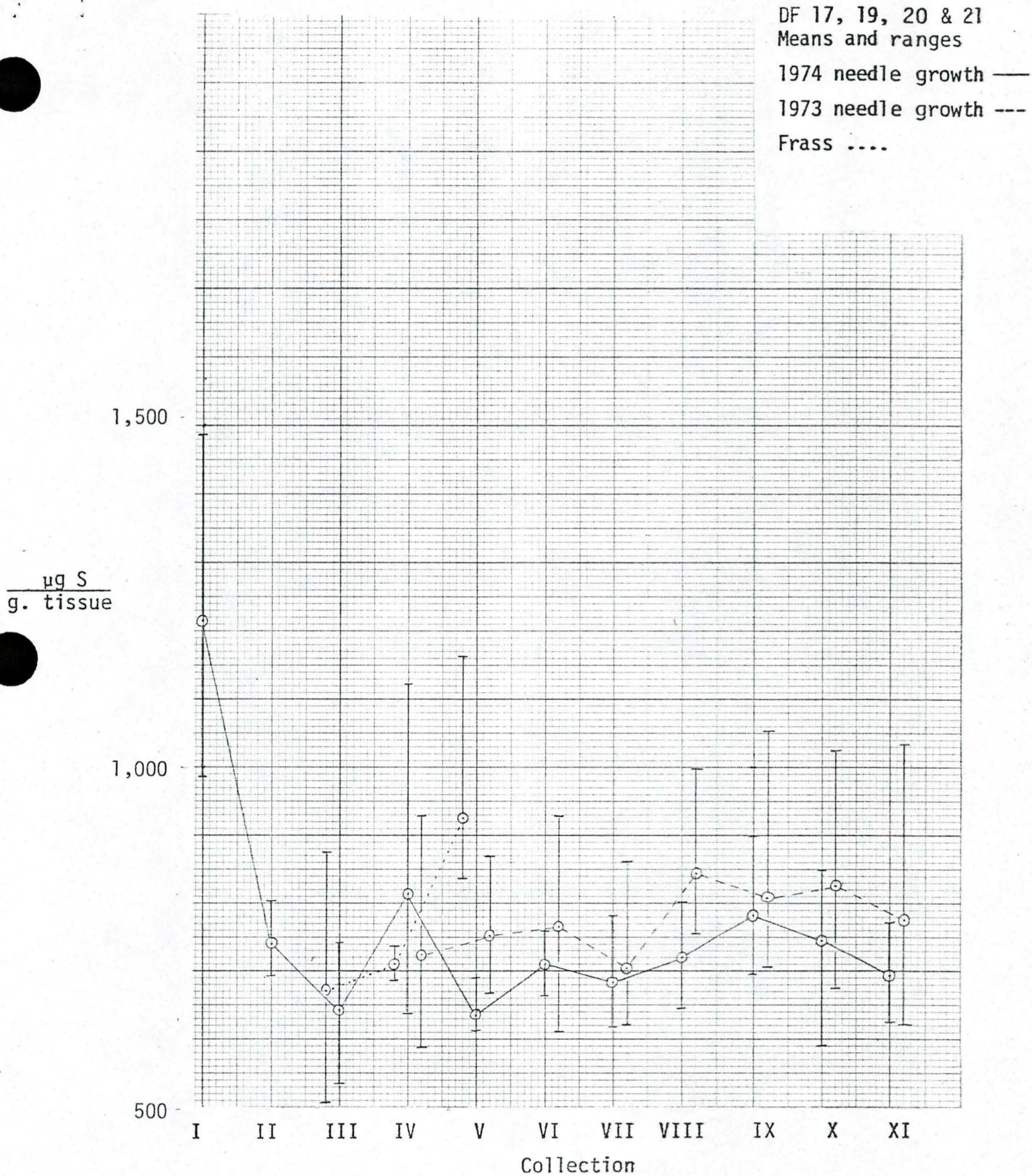

PHOSPHORUS
GF 18, 22, 23 & 24
Means and ranges
1974 needle growth ——
1973 needle growth ---
Frass ····
2,900
2,500
2,100
1,700
1,300
900
500
µg P / g. tissue
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Collection

Figure 7



SULFUR
DF 17, 19, 20 & 21
Means and ranges
1974 needle growth ——
1973 needle growth ---
Frass ....
1,500
1,000
500
μg S / g. tissue
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Collection

Figure 8

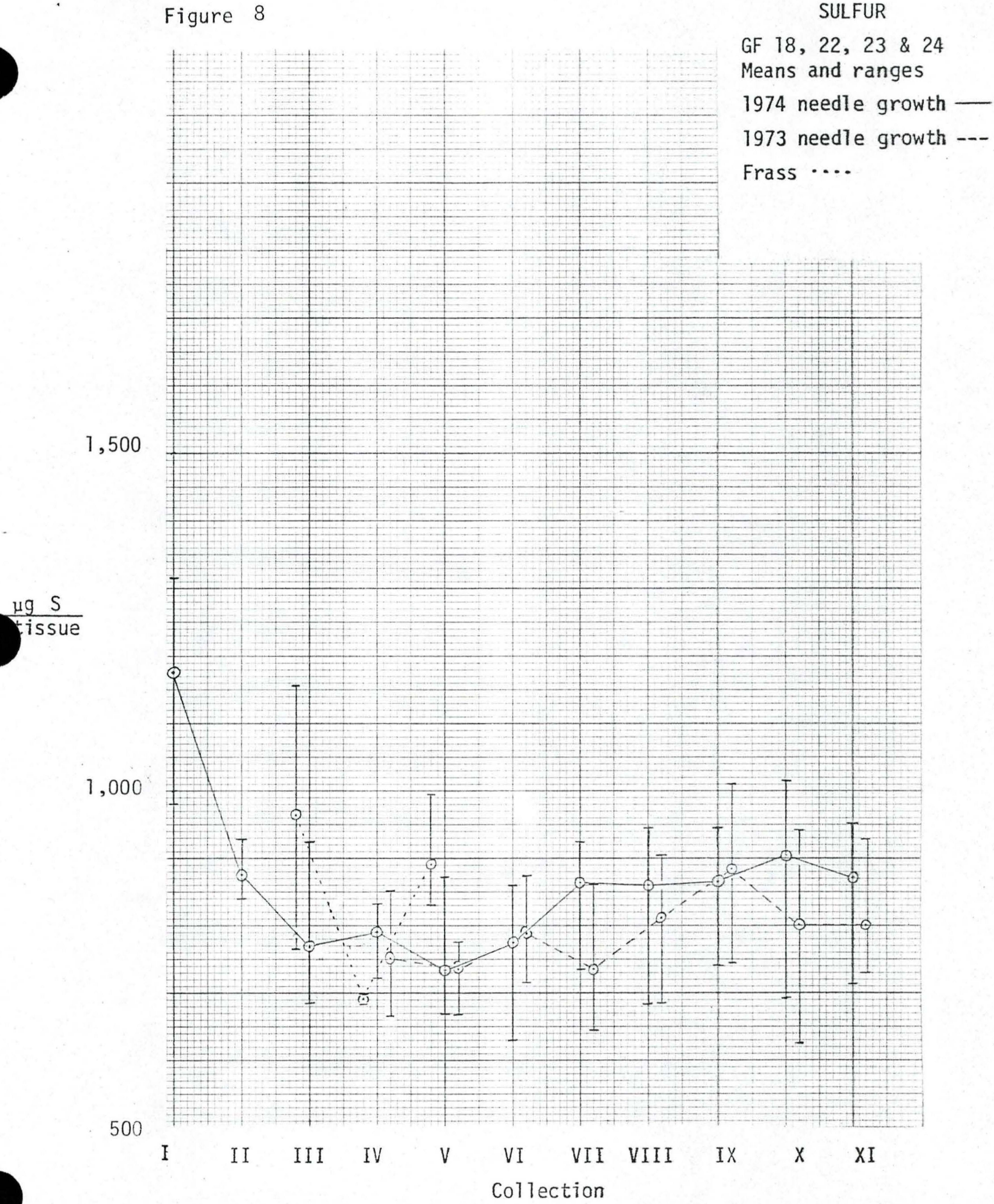

SULFUR
GF 18, 22, 23 & 24
Means and ranges
1974 needle growth ——
1973 needle growth ---
Frass ····
1,500
μg S
tissue
1,000
500
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Collection

Figure 9

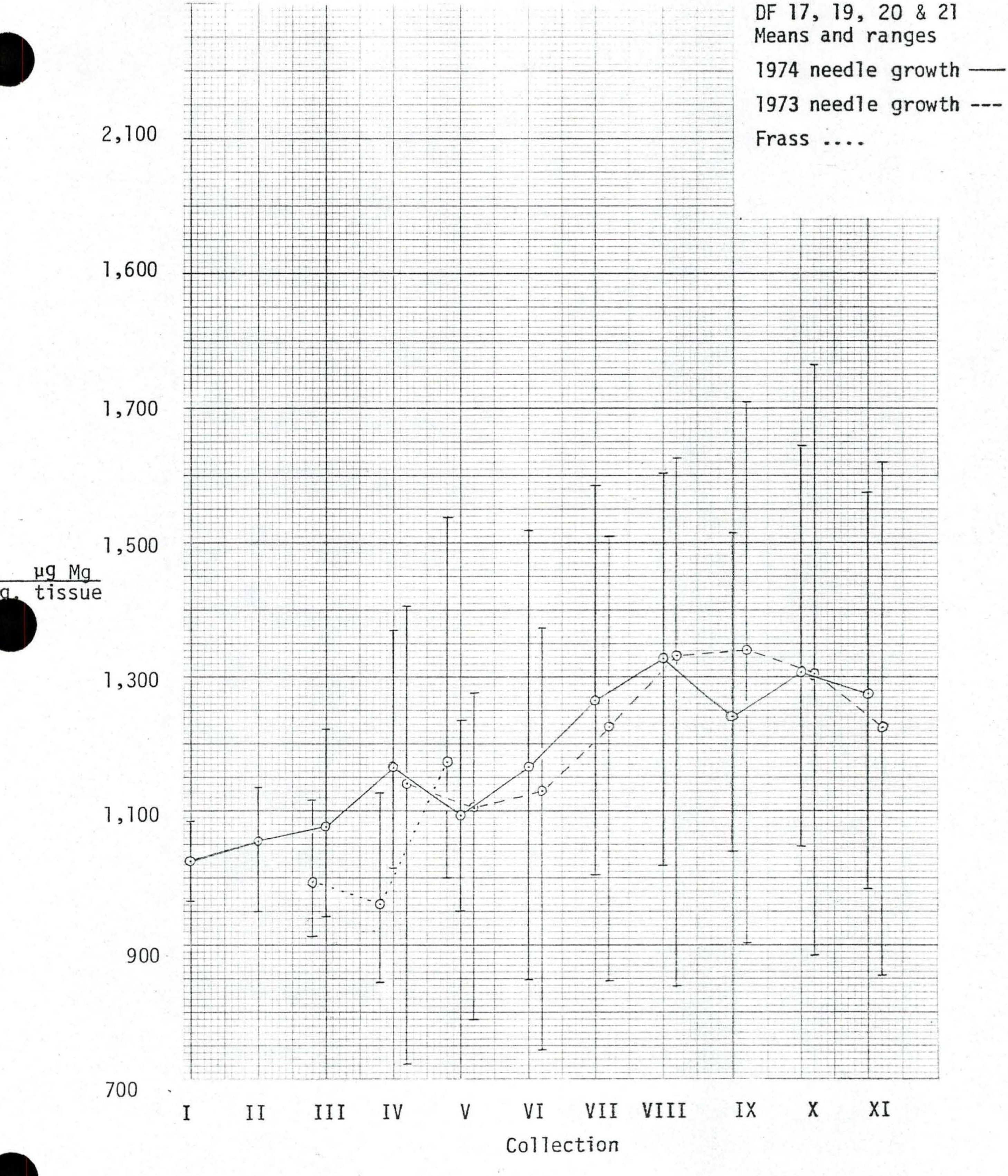

MAGNESIUM
DF 17, 19, 20 & 21
Means and ranges
1974 needle growth ——
1973 needle growth ---
Frass ....
2,100
1,600
1,700
1,500
µg Mg / g. tissue
1,300
1,100
900
700
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Collection

Figure 10

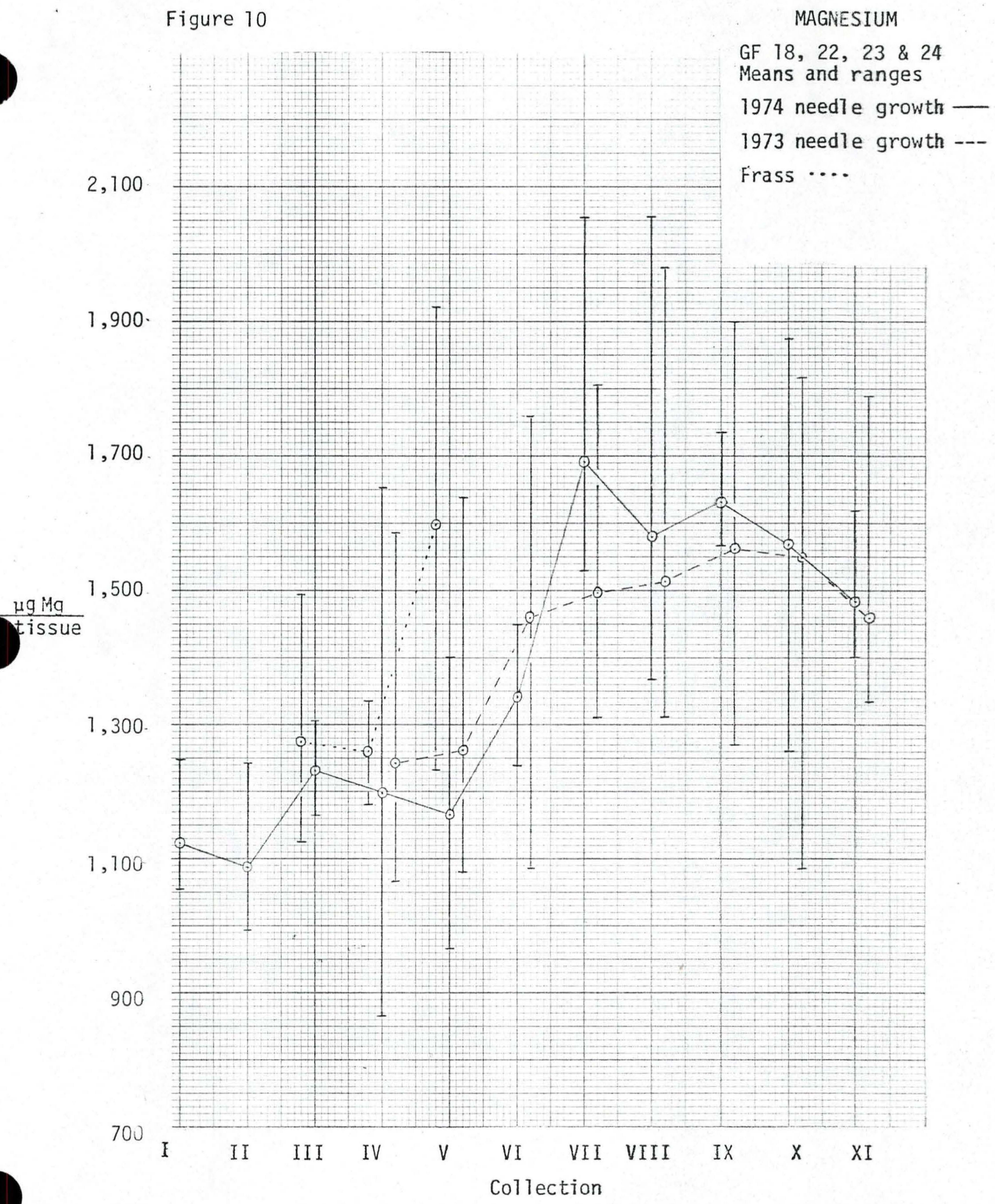

MAGNESIUM
GF 18, 22, 23 & 24
Means and ranges
1974 needle growth ——
1973 needle growth ---
Frass ····
2,100
1,900
1,700
1,500
1,300
1,100
900
700
μg Mg
tissue
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Collection

Figure 11

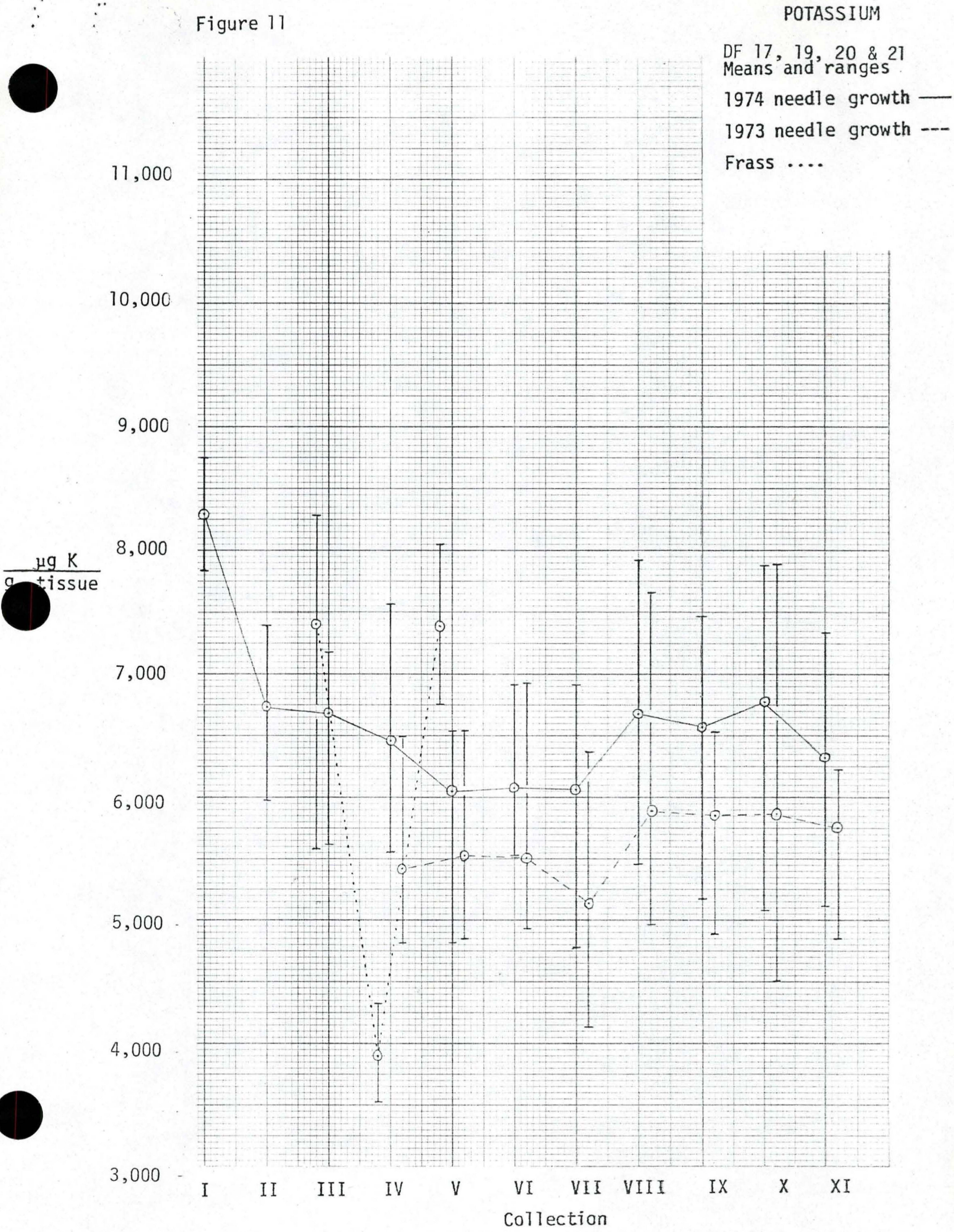

POTASSIUM
DF 17, 19, 20 & 21
Means and ranges
1974 needle growth ——
1973 needle growth ---
Frass ....
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
µg K / g tissue
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Collection

Figure 12

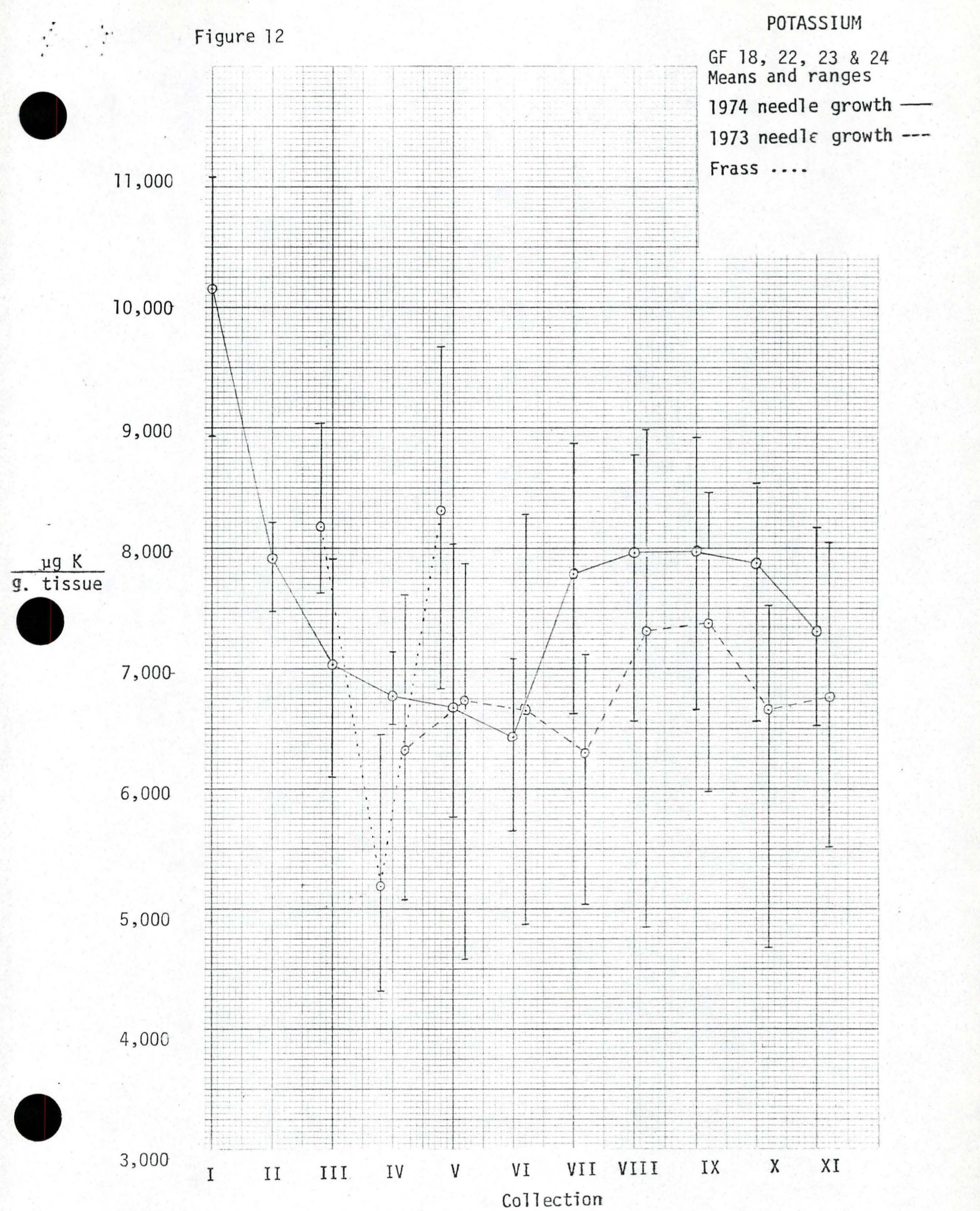

POTASSIUM
GF 18, 22, 23 & 24
Means and ranges
1974 needle growth ——
1973 needle growth ---
Frass ....
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
μg K / g. tissue
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Collection

Table 17 (Phase 2)
Concentration Data

Frass, Watershed 1, Traps 5 - 25 — µg Nutrient/Gram Tissue —

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
5	I	4.59	14,882	807	452	441	465	6,397
	III	2.33	10,748	1,447	4,992	1,229	672	8,400
	IV	4.36	20,207	1,000	1,762	572	732	7,306
	V	0.63	---	---	---	---	---	8,591
	(Wgt'd mean) (III,IV,V)		16,913	1,156	2,287	801	711	7,765
	VI	0.030	---	---	---	---	---	14,936
10	I	1.61	15,454	699	450	471	350	5,932
	III	0.27	---	---	---	---	---	7,124
	IV	0.47	---	---	---	---	---	11,220
	V	0.22	---	---	---	---	---	8,096
	(Wgt'd mean) (III,IV,V)		---	---	---	---	---	9,352
	VI	0.042	---	---	---	---	---	14,164
15	I	0.49	---	---	---	---	---	6,223
	III	1.00	6,880	1,173	8,150	1,518	694	6,685
	IV	2.38	10,644	1,068	7,086	1,328	709	7,350
	V	0.33	---	---	---	---	---	9,018
	(Wgt'd mean) (III,IV,V)		9,530	1,099	7,401	1,384	705	7,319
	VI	0.519	---	---	---	---	---	12,237
20	I	6.64	14,551	706	533	492	449	6,636
	III	4.06	11,827	1,233	5,315	1,055	630	7,167
	IV	7.41	19,329	723	1,985	538	567	6,976
	V	1.80	18,657	713	1,063	554	606	7,784
	(Wgt'd mean) (III,IV,V)		16,943	878	2,879	698	592	7,144
	VI	0.116	---	---	---	---	---	12,673
25	I	---	---	---	---	---	---	---
	III	0.22	---	---	---	---	---	5,844
	IV	0.03	---	---	---	---	---	---
	V	0.12	---	---	---	---	---	7,172
	(Wgt'd mean) (III,IV,V)		---	---	---	---	---	6,313
	VI	0.034	---	---	---	---	---	---

Table 17 (Phase 2)
Concentration Data

Frass, Watershed 1, Traps 30 - 50

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	µg Nutrient/Gram Tissue					
			Ca	Mg	K	P	S	N
30	I	---	---	---	---	---	---	---
	III	3.78	11,367	1,175	5,806	1,178	1,027	7,410
	IV	12.90	17,226	873	3,263	713	721	6,610
	V	1.33	19,440	688	988	596	627	8,482
	(Wgt'd mean) (III,IV,V)		16,160	923	3,629	802	778	7,632
	VI	0.105	---	---	---	---	---	12,171
35	I	7.17	13,546	876	1,616	508	488	6,662
	III	8.30	15,263	1,468	6,302	1,233	828	7,610
	IV	14.68	20,760	1,233	4,223	888	721	8,605
	V	1.93	21,002	821	823	598	588	8,805
	(Wgt'd mean) (III,IV,V)		18,947	1,279	4,652	980	746	8,289
	VI	0.102	---	---	---	---	---	13,279
40	I	4.28	14,882	854	918	488	484	6,340
	III	1.90	12,929	1,405	6,344	1,257	804	7,253
	IV	4.20	19,520	863	1,985	634	644	8,076
	V	1.01	16,859	834	1,301	655	721	8,832
	(Wgt'd mean) (III,IV,V)		17,381	1,004	3,053	803	698	7,963
	VI	0.251	---	---	---	---	---	12,048
45	I	3.65	10,799	755	683	392	388	5,518
	III	5.56	10,275	1,126	6,565	1,261	768	6,398
	IV	9.25	14,976	745	2,424	590	754	6,742
	V	1.50	14,571	709	1,297	653	625	8,194
	(Wgt'd mean) (III,IV,V)		13,336	872	3,732	825	747	6,758
	VI	0.130	---	---	---	---	---	11,559
50	I	2.95	12,872	829	612	412	411	6,096
	III	2.83	13,619	1,707	4,662	1,285	686	7,386
	IV	5.33	18,487	887	1,363	472	526	7,345
	V	1.79	16,827	793	846	556	547	8,738
	(Wgt'd mean) (III,IV,V)		16,804	1,103	2,208	718	575	7,607
	VI	0.380	---	---	---	---	---	13,030

Table 18 (Phase 2)
Concentration Data

Frass, Watershed 4, Traps 5 - 25 — µg Nutrient/Gram Tissue —

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
5	I	0.55	---	---	---	---	---	6,871
	III	0.71	11,108	1,580	5,970	1,133	893	7,825
	IV	5.74	14,883	1,712	5,912	1,154	948	8,301
	V	2.09	15,913	687	921	419	536	6,974
	(Wgt'd mean) (III,IV,V)		14,821	1,450	4,695	972	843	7,937
	VI	0.228	---	---	---	---	---	9,748
10	I	0.85	13,601	709	294	407	378	6,763
	III	---	---	---	---	---	---	---
	IV	2.68	6,805	1,167	5,964	1,253	672	7,531
	V	0.13	---	---	---	---	---	10,017
	(Wgt'd mean) (III,IV,V)		6,805	1,167	5,964	1,253	672	7,646
	VI	0.651	---	---	---	---	---	12,067
15	I	0.156	---	---	---	---	---	5,368
	III	0.04	---	---	---	---	---	---
	IV	0.41	---	---	---	---	---	6,817
	V	0.12	---	---	---	---	---	7,422
	(Wgt'd mean) (III,IV,V)							6,954
	VI	0.095	---	---	---	---	---	10,109
20	I	0.05	---	---	---	---	---	5,008
	III	1.86	8,831	1,468	5,081	1,423	809	7,802
	IV	1.26	12,875	800	1,295	427	426	6,722
	V	0.30	---	---	---	---	---	7,107
	(Wgt'd mean) (III,IV,V)		10,464	1,198	3,552	1,021	654	7,343
	VI	0.130	---	---	---	---	---	10,285
25	I	0.33	---	---	---	---	---	6,572
	III	0.30	---	---	---	---	---	8,067
	IV	7.66	8,612	1,046	4,340	969	697	7,170
	V	1.29	10,741	813	1,156	555	566	7,745
	(Wgt'd mean) (III,IV,V)		8,919	1,012	3,881	909	678	7,279
	VI	0.157	---	---	---	---	---	10,815

Table 18 (Phase 2)
Concentration Data

Frass, Watershed 4, Traps 30 - 50

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
			μg Nutrient/Gram Tissue					
30	I	0.59	---	---	---	---	---	5,681
	III	3.03	8,878	1,106	5,944	2,120	896	9,605
	IV	12.82	11,071	947	5,873	1,225	912	8,427
	V	2.73	14,193	610	1,153	514	499	7,149
	(Wgt'd mean) (III,IV,V)		11,172	923	5,191	1,266	849	8,431
	VI	0.363	---	---	---	---	---	10,762
35	I	0.36	---	---	---	---	---	5,739
	III	1.66	9,403	1,395	5,873	1,384	896	9,007
	IV	4.60	15,119	1,050	3,104	631	642	7,524
	V	0.99	15,728	783	924	540	566	7,578
	(Wgt'd mean) (III,IV,V)		13,893	1,093	3,440	791	690	7,871
	VI	0.304	---	---	---	---	---	12,597
40	I	2.74	15,276	634	456	461	402	5,981
	III	2.88	17,428	1,298	4,531	1,114	775	7,231
	IV	9.55	24,619	1,355	4,969	1,074	801	8,464
	V	1.29	26,521	610	921	499	592	8,248
	(Wgt'd mean) (III,IV,V)		23,288	1,273	4,496	1,028	776	8,185
	VI	0.185	---	---	---	---	---	11,740
45	I	0.36	---	---	---	---	---	6,179
	III	2.54	8,687	1,173	7,157	1,360	757	7,164
	IV	13.03	13,214	1,196	6,944	1,289	902	8,464
	V	1.53	15,722	713	1,229	522	527	7,636
	(Wgt'd mean) (III,IV,V)		12,766	1,149	6,464	1,231	847	8,197
	VI	0.173	---	---	---	---	---	12,428
50	I	1.48	13,219	757	685	441	475	8,542
	III	10.10	15,459	1,110	4,734	1,031	759	8,349
	IV	15.30	20,445	963	3,423	699	665	8,404
	V	2.32	19,019	752	1,064	580	651	8,598
	(Wgt'd mean) (III,IV,V)		18,509	999	3,703	810	698	8,400
	VI	0.212	---	---	---	---	---	9,095

Table 19 (Phase 2)
Concentration Data

Needles, Watershed 1, Traps 5 - 25 — µg Nutrient/Gram Tissue —

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
5	I	14.24	18,278	1,421	2,774	1,154	889	9,287
	III	2.24	9,632	1,397	7,345	1,870	929	13,012
	IV	2.00	12,040	1,173	3,412	1,253	848	13,104
	V	15.59	18,738	1,478	2,281	861	703	8,824
	(Wgt'd mean) (III,IV,V)		17,034	1,438	2,967	1,015	743	9,729
	VI	46.34	12,495	1,086	1,766	937	755	9,706
10	I	14.42	26,046	1,660	3,462	845	687	9,314
	III	2.42	8,016	1,270	8,488	2,054	1,000	13,668
	IV	2.50	13,244	937	2,862	1,217	764	12,435
	V	11.21	22,050	1,437	3,020	929	777	9,176
	(Wgt'd mean) (III,IV,V)		18,580	1,334	3,816	1,142	808	10,355
	VI	33.38	15,798	904	1,677	1,056	816	9,514
15	I	12.00	21,231	1,448	3,912	1,032	824	8,655
	III	2.10	10,718	1,113	7,299	1,615	864	11,123
	IV	2.21	14,052	1,114	5,352	1,493	822	10,333
	V	11.91	18,947	1,287	3,412	1,071	668	8,761
	(Wgt'd mean) (III,IV,V)		17,215	1,241	4,180	1,199	714	9,281
	VI	57.32	15,010	1,003	2,346	1,164	872	9,080
20	I	18.52	21,317	1,160	3,658	1,116	822	7,526
	III	4.48	9,080	1,183	7,109	1,557	839	11,665
	IV	5.13	16,310	912	3,446	1,138	906	11,259
	V	23.40	17,799	1,003	2,705	845	678	7,904
	(Wgt'd mean) (III,IV,V)		16,384	1,013	3,418	987	735	8,936
	VI	61.95	15,532	990	2,674	1,077	893	10,127
25	I	---	---	---	---	---	---	---
	III	0.95	8,764	934	6,872	1,568	770	10,074
	IV	0.49	11,707	820	3,040	1,015	660	11,281
	V	3.73	11,913	753	2,220	1,026	556	9,037
	(Wgt'd mean) (III,IV,V)		11,315	793	3,153	1,125	605	9,440
	VI	29.04	11,261	1,013	1,610	856	632	12,986

Table 19 (Phase 2)
Concentration Data

Needles, Watershed 1, Traps 30 - 50 — µg Nutrient/Gram Tissue —

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
30	I	---	---	---	---	---	---	---
	III	2.23	11,158	1,258	7,013	1,672	922	11,769
	IV	6.19	15,433	1,070	4,369	1,174	829	10,340
	V	22.96	18,648	1,229	2,732	822	770	8,621
	(Wgt'd mean) (III,IV,V)		17,482	1,200	3,359	952	792	9,184
	VI	49.05	16,378	1,050	2,609	1,049	856	10,106
35	I	139.28	17,304	1,284	4,804	1,174	951	11,254
	III	8.58	8,684	1,344	7,451	1,782	1,081	14,249
	IV	9.50	11,311	1,120	5,406	1,449	938	12,888
	V	20.27	19,247	1,318	2,068	970	756	10,129
	(Wgt'd mean) (III,IV,V)		14,918	1,275	4,099	1,270	874	11,734
	VI	58.41	16,632	1,311	2,746	1,342	1,040	8,013
40	I	28.61	19,026	1,079	3,621	1,062	856	7,227
	III	3.31	8,248	1,468	8,417	2,088	1,037	15,346
	IV	3.36	11,497	862	3,211	1,302	825	14,515
	V	14.29	18,033	1,039	2,482	1,056	801	9,046
	(Wgt'd mean) (III,IV,V)		15,440	1,078	3,536	1,258	842	10,918
	VI	42.20	13,000	1,033	1,945	1,181	942	11,007
45	I	20.91	15,532	1,261	3,831	682	632	7,708
	III	5.12	7,381	1,244	8,204	1,905	958	13,426
	IV	4.24	11,064	842	3,584	1,382	864	13,891
	V	14.44	16,033	1,301	2,599	819	727	8,994
	(Wgt'd mean) (III,IV,V)		13,286	1,207	3,980	1,153	801	10,820
	VI	22.25	13,238	937	1,677	1,073	1,029	11,542
50	I	13.32	17,254	1,205	2,494	845	708	6,770
	III	2.89	8,575	1,359	7,015	1,908	1,089	14,465
	IV	3.57	12,379	900	2,806	1,265	903	13,163
	V	15.78	19,455	1,229	2,130	909	684	9,759
	(Wgt'd mean) (III,IV,V)		16,905	1,193	2,873	1,096	772	10,917
	VI	47.12	16,060	893	1,610	1,044	932	10,782

Table [illegible] (Phase 2)
Concentration Data

Needles, Watershed 4, Traps 5 - 25

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
			μg Nutrient/Gram Tissue					
5	I	3.56	21,228	1,321	2,583	918	795	8,850
	III	1.69	9,079	1,409	8,306	1,998	821	13,204
	IV	1.79	11,622	1,452	6,344	1,560	890	12,199
	V	7.33	21,383	1,360	2,288	777	706	7,798
	(Wgt'd mean) (III,IV,V)		17,843	1,383	3,900	1,098	754	9,372
	VI	59.57	22,239	587	928	697	630	7,799
10	I	7.62	20,595	977	2,195	769	717	8,043
	III	---	---	---	---	---	---	---
	IV	2.39	7,502	1,167	5,912	1,536	728	10,425
	V	3.89	9,691	834	2,130	917	656	10,065
	(Wgt'd mean) (III,IV,V)		8,858	961	3,569	1,153	683	10,202
	VI	59.72	15,743	630	1,352	950	768	9,777
15	I	16.88	10,156	719	2,256	874	689	6,710
	III	0.621	5,253	1,383	6,179	1,764	896	12,636
	IV	0.65	7,187	847	2,666	1,261	810	12,854
	V	1.27	9,402	870	1,367	932	741	10,007
	(Wgt'd mean) (III,IV,V)		7,855	994	2,888	1,225	800	11,427
	VI	13.06	8,595	1,083	1,071	845	822	9,279
20	I	3.64	7,674	957	1,683	660	554	6,689
	III	1.35	7,237	1,133	6,159	1,702	893	12,563
	IV	1.28	9,106	782	2,564	1,241	774	12,193
	V	3.17	7,570	790	985	681	526	7,710
	(Wgt'd mean) (III,IV,V)		7,832	868	2,538	1,042	666	9,829
	VI	15.10	8,566	934	992	802	752	8,687
25	I	17.17	15,663	993	2,188	915	896	8,241
	III	4.07	6,662	1,358	7,276	1,889	890	13,144
	IV	5.07	10,234	1,110	4,457	1,353	892	11,287
	V	32.34	14,546	1,010	1,896	890	682	8,789
	(Wgt'd mean) (III,IV,V)		13,245	1,056	2,737	1,045	728	9,522
	VI	49.96	9,357	993	1,225	845	725	8,500

Table 20 (Phase 2)
Concentration Data

Needles, Watershed 4, Traps 30 - 50

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
			μg Nutrient/Gram Tissue					
30	I	6.34	14,175	738	2,338	805	795	7,245
	III	1.52	8,151	1,254	8,275	1,985	880	11,595
	IV	2.15	9,517	944	4,558	1,341	971	10,723
	V	9.20	13,838	632	2,198	779	739	7,399
	(Wgt'd mean) (III,IV,V)		12,444	758	3,310	1,015	794	8,450
	VI	38.52	12,296	575	1,156	882	808	9,055
35	I	11.39	15,013	1,162	1,760	648	816	7,146
	III	1.62	8,987	1,201	6,969	1,841	926	12,725
	IV	1.37	9,595	957	3,326	1,249	1,033	12,153
	V	11.59	16,609	1,147	1,685	676	756	7,625
	(Wgt'd mean) (III,IV,V)		15,103	1,135	2,426	859	801	8,617
	VI	54.42	15,033	829	1,692	1,098	916	10,913
40	I	11.06	30,673	1,007	3,253	732	694	9,150
	III	2.45	10,693	1,096	7,110	1,691	887	11,729
	IV	2.42	14,792	1,117	5,351	1,462	1,004	12,187
	V	25.60	30,080	930	2,816	753	658	7,453
	(Wgt'd mean) (III,IV,V)		27,307	958	3,363	885	704	8,172
	VI	56.22	25,246	803	1,387	875	818	7,893
45	I	8.21	17,209	1,043	4,124	956	787	7,591
	III	2.45	10,701	1,138	7,297	1,895	1,010	13,533
	IV	2.81	12,411	1,036	5,495	1,466	961	12,248
	V	16.40	15,598	804	3,474	853	703	7,660
	(Wgt'd mean) (III,IV,V)		14,631	872	4,169	1,050	771	8,920
	VI	81.50	16,450	930	2,349	1,126	965	9,956
50	I	18.95	17,271	1,157	2,856	910	803	7,915
	III	8.54	7,863	1,254	7,276	1,736	938	10,051
	IV	6.70	11,637	1,107	4,003	1,452	1,156	14,466
	V	23.58	16,087	1,000	2,372	923	804	9,850
	(Wgt'd mean) (III,IV,V)		13,510	1,074	3,732	1,193	894	10,691
	VI	83.12	16,270	723	998	776	679	7,866

Special note concerning Tables 21 and 22 (Phase 2):

One or more of the three collections made in 1973 (III, IV and V) did not provide enough frass for analysis of Ca, Mg, K, P or S. For samples weighing between 0.7 and 0.004 grams only nitrogen was analyzed. Consequently two totals frass weights (wgt/wgt') are recorded for the traps to which this applies. The first weight is used in the calculations of weighted mean concentrations for Ca, Mg, K, P and S; the second for N only (see Tables 17-20).

Table 21 (Phase 2)
A[illegible]s
Fr[illegible], Watershed 1, traps 5 - 25

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
			Kilograms nutrient/hectare					
5	I	4.59	2.723	0.148	0.083	0.081	0.085	1.171
	III	2.33	0.998	0.134	0.464	0.114	0.062	0.780
	IV	4.36	3.512	0.174	0.306	0.099	0.127	1.270
	V	0.63						0.216
	Σ(III,IV,V)	6.69/7.32	4.510	0.308	0.770	0.213	0.189	2.266
	VI	0.030						0.018
10	I	1.61	0.992	0.045	0.029	0.030	0.022	0.381
	III	0.27						0.077
	IV	0.47						0.210
	V	0.22						0.071
	Σ(III,IV,V)	0.96						0.358
	VI	0.042						0.024
15	I	0.49						0.122
	III	1.00	0.274	0.047	0.325	0.061	0.028	0.267
	IV	2.38	1.010	0.101	0.672	0.126	0.067	0.697
	V	0.33						0.119
	Σ(III,IV,V)	3.38/3.71	1.284	0.148	0.997	0.187	0.095	1.083
	VI	0.519						0.253
20	I	6.64	3.852	0.187	0.141	0.130	0.119	1.757
	III	4.06	1.914	0.200	0.860	0.171	0.102	1.160
	IV	7.41	5.710	0.214	0.586	0.159	0.167	2.061
	V	1.80	1.339	0.051	0.076	0.040	0.043	0.559
	Σ(III,IV,V)	13.27	8.963	0.465	1.522	0.370	0.312	3.780
	VI	0.116						0.059
25	I							
	III	0.22						0.051
	IV	0.03						
	V	0.12						0.034
	Σ(III,IV,V)	0.34						0.085
	VI	0.034						

Table 21 (Phase 2)
A[illegible]ts
F[illegible], Watershed 1, Traps 30-50

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
			Kilograms nutrient/hectare					
30	I							
	III	3.78	1.713	0.177	0.875	0.178	0.155	1.117
	IV	12.90	8.859	0.449	1.678	0.367	0.371	3.914
	V	1.33	1.031	0.036	0.052	0.032	0.033	0.450
	Σ(III,IV,V)	18.01	11.603	0.662	2.605	0.577	0.559	5.481
	VI	0.105						0.051
35	I	7.17	3.872	0.250	0.462	0.145	0.139	1.904
	III	8.30	5.050	0.486	2.085	0.408	0.274	2.518
	IV	14.68	12.149	0.722	2.471	0.520	0.422	5.036
	V	1.93	1.616	0.063	0.063	0.046	0.045	0.677
	Σ(III,IV,V)	24.91	18.815	1.271	4.619	0.974	0.741	8.231
	VI	0.102						0.054
40	I	4.28	2.539	0.146	0.157	0.083	0.083	1.082
	III	1.90	0.979	0.106	0.481	0.095	0.061	0.549
	IV	4.20	3.268	0.144	0.332	0.106	0.108	1.352
	V	1.01	0.679	0.034	0.052	0.026	0.029	0.356
	Σ(III,IV,V)	7.11	4.926	0.284	0.865	0.227	0.198	2.257
	VI	0.251						0.121
45	I	3.65	1.571	0.110	0.099	0.057	0.056	0.803
	III	5.56	2.278	0.250	1.455	0.280	0.170	1.418
	IV	9.25	5.523	0.275	0.894	0.218	0.278	2.486
	V	1.50	0.871	0.042	0.078	0.039	0.037	0.490
	Σ(III,IV,V)	16.31	8.672	0.567	2.427	0.537	0.485	4.394
	VI	0.130						0.060
50	I	2.95	1.514	0.097	0.072	0.048	0.048	0.717
	III	2.83	1.537	0.193	0.526	0.145	0.077	0.833
	IV	5.33	3.928	0.188	0.290	0.100	0.122	1.561
	V	1.79	1.201	0.057	0.060	0.040	0.039	0.624
	Σ(III,IV,V)	9.95	6.666	0.438	0.876	0.285	0.238	3.018
	VI	0.380						0.197

Table 22 (Phase 2)
A[illegible]ts
F[illegible], Watershed 4, Traps 5-25

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
			Kilograms nutrient/hectare					
5	I	0.55						0.151
	III	0.71	0.314	0.045	0.169	0.032	0.025	0.221
	IV	5.74	3.406	0.392	1.353	0.264	0.217	1.900
	V	2.09	1.326	0.057	0.077	0.035	0.045	0.581
	Σ(III,IV,V)	8.54	5.046	0.494	1.599	0.331	0.287	2.702
	VI	0.228						0.089
10	I	0.85	0.461	0.024	0.010	0.014	0.013	0.229
	III							
	IV	2.68	0.727	0.125	0.637	0.134	0.072	0.805
	V	0.13						0.052
	Σ(III,IV,V)	2.68/2.81	0.727	0.125	0.637	0.134	0.072	0.857
	VI	0.651						0.313
15	I	0.156						0.033
	III	0.04						
	IV	0.41						0.111
	V	0.12						0.036
	Σ(III,IV,V)	0.53						0.147
	VI	0.095						0.038
20	I	0.05						0.010
	III	1.86	0.655	0.109	0.377	0.106	0.060	0.579
	IV	1.26	0.647	0.040	0.065	0.021	0.021	0.338
	V	0.30						0.085
	Σ(III,IV,V)	3.12/3.42	1.302	0.149	0.442	0.127	0.081	1.002
	VI	0.130						0.053
25	I	0.33						0.086
	III	0.30						0.096
	IV	7.66	2.630	0.319	1.325	0.296	0.213	2.190
	V	1.29	0.552	0.042	0.059	0.029	0.029	0.398
	Σ(III,IV,V)	8.95/9.25	3.182	0.361	1.384	0.325	0.242	2.684
	VI	0.157						0.068

Table 22 (Phase 2)
A[illegible]s
Frass, Watershed 4, Traps 30-50

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Kilograms nutrient/hectare Ca	Mg	K	P	S	N
30	I	0.59						0.134
	III	3.03	1.072	0.134	0.718	0.256	0.108	1.160
	IV	12.82	5.658	0.484	3.002	0.626	0.466	4.307
	V	2.73	1.545	0.066	0.125	0.056	0.054	0.778
	Σ(III,IV,V)	18.58	8.275	0.684	3.845	0.938	0.628	6.245
	VI	0.363						0.156
35	I	0.36						0.082
	III	1.66	0.622	0.092	0.389	0.092	0.059	0.596
	IV	4.60	2.773	0.193	0.569	0.116	0.118	1.380
	V	0.99	0.621	0.031	0.036	0.021	0.022	0.299
	Σ(III,IV,V)	7.25	4.016	0.316	0.994	0.229	0.199	2.275
	VI	0.304						0.153
40	I	2.74	1.669	0.069	0.050	0.050	0.044	0.653
	III	2.88	2.001	0.149	0.520	0.128	0.089	0.830
	IV	9.55	9.373	0.516	1.892	0.409	0.305	3.222
	V	1.29	1.364	0.031	0.047	0.026	0.030	0.424
	Σ(III,IV,V)	13.72	12.738	0.696	2.459	0.563	0.424	4.476
	VI	0.185						0.087
45	I	0.36						0.089
	III	2.54	0.880	0.119	0.725	0.138	0.077	0.725
	IV	13.03	6.864	0.621	3.607	0.670	0.469	4.397
	V	1.53	0.959	0.043	0.075	0.032	0.032	0.466
	Σ(III,IV,V)	17.10	8.703	0.783	4.407	0.840	0.578	5.588
	VI	0.173						0.086
50	I	1.48	0.780	0.045	0.040	0.026	0.028	0.504
	III	10.10	6.225	0.447	1.906	0.415	0.306	3.362
	IV	15.30	12.470	0.587	2.088	0.426	0.406	5.126
	V	2.32	1.759	0.070	0.098	0.054	0.060	0.795
	Σ(III,IV,V)	27.72	20.454	1.104	4.092	0.895	0.772	9.283
	VI	0.212						0.077

Table 23 (Phase 2)
A[illegible]ts
N[illegible]es, Watershed 1, Traps 5-25

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
			Kilograms nutrient/hectare					
5	I	14.24	10.376	0.807	1.575	0.655	0.505	5.272
	III	2.24	0.860	0.125	0.656	0.167	0.083	1.162
	IV	2.00	0.960	0.094	0.272	0.100	0.068	1.045
	V	15.59	11.646	0.919	1.418	0.535	0.437	5.484
	Σ(III,IV,V)	19.83	13.466	1.138	2.346	0.802	0.588	7.691
	VI	46.34	23.083	2.006	3.262	1.731	1.395	17.931
10	I	14.42	14.973	0.954	1.990	0.486	0.395	5.354
	III	2.42	0.773	0.123	0.819	0.198	0.096	1.319
	IV	2.50	1.320	0.093	0.285	0.121	0.076	1.239
	V	11.21	9.854	0.642	1.350	0.415	0.347	4.101
	Σ(III,IV,V)	16.13	11.947	0.858	2.454	0.734	0.519	6.659
	VI	33.38	21.023	1.203	2.232	1.405	1.086	12.661
15	I	12.00	10.157	0.693	1.871	0.494	0.394	4.140
	III	2.10	0.897	0.093	0.611	0.135	0.072	0.931
	IV	2.21	1.238	0.098	0.472	0.132	0.072	0.910
	V	11.91	8.996	0.611	1.620	0.509	0.317	4.160
	Σ(III,IV,V)	16.22	11.131	0.802	2.703	0.776	0.461	6.001
	VI	57.32	34.300	2.292	5.361	2.660	1.993	20.749
20	I	18.52	15.739	0.856	2.701	0.824	0.607	5.557
	III	4.48	1.622	0.211	1.270	0.278	0.150	2.083
	IV	5.13	3.336	0.187	0.705	0.233	0.185	2.303
	V	23.40	16.604	0.936	2.523	0.788	0.632	7.373
	Σ(III,IV,V)	33.01	21.562	1.334	4.498	1.299	0.967	11.759
	VI	61.95	38.359	2.445	6.604	2.660	2.205	25.011
25	I							
	III	0.95	0.332	0.035	0.260	0.059	0.029	0.382
	IV	0.49	0.229	0.016	0.059	0.020	0.013	0.220
	V	3.73	1.771	0.112	0.330	0.153	0.083	1.344
	Σ(III,IV,V)	5.17	2.332	0.163	0.649	0.232	0.125	1.946
	VI	29.04	13.037	1.173	1.864	0.991	0.732	15.034

Table 23 (Phase 2)
A[illegible]ts
N[illegible]es, Watershed 1, Traps 30-50

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
			Kilograms nutrient/hectare					
30	I							
	III	2.23	0.992	0.112	0.623	0.149	0.082	1.046
	IV	6.19	3.808	0.264	1.078	0.290	0.205	2.552
	V	22.96	17.069	1.125	2.501	0.752	0.705	7.891
	Σ(III,IV,V)	31.38	21.869	1.501	4.202	1.191	0.992	11.489
	VI	49.05	32.026	2.053	5.102	2.051	1.674	19.762
35	I	139.28	96.081	7.129	26.674	6.519	5.280	62.488
	III	8.58	2.970	0.460	2.549	0.610	0.370	4.874
	IV	9.50	4.284	0.424	2.047	0.549	0.355	4.881
	V	20.27	15.553	1.065	1.671	0.784	0.611	8.185
	Σ(III,IV,V)	38.35	22.807	1.949	6.267	1.943	1.336	17.940
	VI	58.41	38.729	3.053	6.394	3.125	2.422	18.659
40	I	28.61	21.700	1.231	4.130	1.211	0.976	8.243
	III	3.31	1.088	0.194	1.111	0.276	0.137	2.025
	IV	3.36	1.540	0.115	0.430	0.174	0.111	1.944
	V	14.29	10.273	0.592	1.414	0.602	0.456	5.153
	Σ(III,IV,V)	20.96	12.901	0.901	2.955	1.052	0.704	9.122
	VI	42.20	21.870	1.738	3.272	1.987	1.585	18.518
45	I	20.91	12.947	1.051	3.194	0.569	0.527	6.425
	III	5.12	1.507	0.254	1.675	0.389	0.196	2.740
	IV	4.24	1.870	0.142	0.606	0.234	0.146	2.348
	V	14.44	9.230	0.749	1.496	0.471	0.419	5.178
	Σ(III,IV,V)	23.80	12.607	1.145	3.777	1.094	0.761	10.266
	VI	22.25	11.742	0.831	1.488	0.952	0.913	10.238
50	I	13.32	9.162	0.640	1.324	0.449	0.376	3.595
	III	2.89	0.988	0.157	0.808	0.220	0.125	1.667
	IV	3.57	1.762	0.128	0.399	0.180	0.129	1.873
	V	15.78	12.239	0.773	1.340	0.572	0.430	6.139
	Σ(III,IV,V)	22.24	14.989	1.058	2.547	0.972	0.684	9.679
	VI	47.12	30.168	1.677	3.024	1.961	1.751	20.254

Table 24 (Phase 2)
Amounts
Needles, Watershed 4, Traps 5-25

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
			Kilograms nutrient/hectare					
5	I	3.56	3.013	0.187	0.367	0.130	0.113	1.256
	III	1.69	0.612	0.095	0.560	0.135	0.055	0.890
	IV	1.79	0.829	0.104	0.453	0.111	0.064	0.871
	V	7.33	6.248	0.397	0.669	0.227	0.206	2.279
	Σ(III,IV,V)	10.81	7.689	0.596	1.682	0.473	0.325	4.040
	VI	59.57	52.814	1.394	2.204	1.655	1.496	18.521
10	I	7.62	6.256	0.297	0.667	0.234	0.218	2.443
	III							
	IV	2.39	0.715	0.111	0.563	0.146	0.069	0.993
	V	3.89	1.503	0.129	0.330	0.142	0.102	1.561
	Σ(III,IV,V)	6.28	2.218	0.240	0.893	0.288	0.171	2.554
	VI	59.72	37.481	1.500	3.219	2.262	1.828	23.277
15	I	16.88	6.834	0.484	1.518	0.588	0.464	4.515
	III	0.621	0.130	0.034	0.153	0.044	0.022	0.313
	IV	0.65	0.186	0.022	0.069	0.033	0.021	0.333
	V	1.27	0.476	0.044	0.069	0.047	0.038	0.507
	Σ(III,IV,V)	2.53	0.792	0.100	0.291	0.124	0.081	1.153
	VI	13.06	4.475	0.564	0.558	0.440	0.428	4.831
20	I	3.64	1.114	0.139	0.244	0.096	0.080	0.971
	III	1.35	0.390	0.061	0.331	0.092	0.048	0.676
	IV	1.28	0.465	0.040	0.131	0.063	0.039	0.626
	V	3.17	0.957	0.100	0.124	0.086	0.066	0.974
	Σ(III,IV,V)	5.80	1.812	0.201	0.586	0.241	0.153	2.276
	VI	15.10	5.166	0.562	0.597	0.483	0.453	5.229
25	I	17.17	10.721	0.680	1.498	0.626	0.613	5.641
	III	4.07	1.081	0.220	1.181	0.306	0.144	2.133
	IV	5.07	2.069	0.224	0.910	0.273	0.180	2.281
	V	32.34	18.754	1.302	2.444	1.147	0.879	11.331
	Σ(III,IV,V)	41.48	21.904	1.746	4.526	1.726	1.203	15.745
	VI	49.96	18.636	1.978	2.440	1.683	1.444	16.929

Tab[illegible]4, (Phase 2)
Am[illegible]s
Needles, Watershed 4, Traps 30-50

Trap	Collection	Tot. Wgt. Trapped Raw Material (g)	Ca	Mg	K	P	S	N
			Kilograms nutrient/hectare					
30	I	6.43	3.634	0.189	0.599	0.206	0.204	1.857
	III	1.52	0.494	0.076	0.501	0.120	0.053	0.703
	IV	2.15	0.816	0.081	0.391	0.115	0.083	0.919
	V	9.20	5.075	0.232	0.806	0.286	0.271	2.714
	Σ(III,IV,V)	12.87	6.385	0.389	1.698	0.521	0.407	4.336
	VI	38.52	18.882	0.883	1.775	1.354	1.241	13.905
35	I	11.39	6.817	0.528	0.799	0.294	0.371	3.245
	III	1.62	0.580	0.078	0.450	0.119	0.060	0.822
	IV	1.37	0.524	0.052	0.182	0.068	0.056	0.664
	V	11.59	7.674	0.530	0.779	0.312	0.349	3.523
	Σ(III,IV,V)	14.58	8.778	0.660	1.411	0.499	0.465	5.009
	VI	54.42	32.614	1.799	3.671	2.382	1.987	23.676
40	I	11.06	13.524	0.444	1.434	0.323	0.306	4.034
	III	2.45	1.044	0.107	0.694	0.165	0.087	1.146
	IV	2.42	1.427	0.108	0.516	0.141	0.097	1.176
	V	25.60	30.699	0.949	2.874	0.768	0.672	7.605
	Σ(III,IV,V)	30.47	33.170	1.164	4.084	1.074	0.856	9.927
	VI	56.22	56.583	1.800	3.109	1.961	1.833	17.690
45	I	8.21	5.633	0.341	1.350	0.313	0.258	2.485
	III	2.45	1.045	0.111	0.713	0.185	0.099	1.322
	IV	2.81	1.390	0.116	0.616	0.164	0.108	1.372
	V	16.40	10.198	0.526	2.271	0.558	0.460	5.008
	Σ(III,IV,V)	21.66	12.633	0.753	3.600	0.907	0.667	7.702
	VI	81.50	53.447	3.022	7.632	3.658	3.135	32.348
50	I	18.95	13.048	0.874	2.158	0.687	0.607	5.979
	III	8.54	2.677	0.427	2.477	0.591	0.319	3.422
	IV	6.70	3.108	0.296	1.069	0.388	0.309	3.864
	V	23.58	15.122	0.940	2.230	0.868	0.756	9.259
	Σ(III,IV,V)	38.32	20.907	1.663	5.776	1.847	1.384	16.545
	VI	83.12	53.913	2.396	3.307	2.571	2.250	26.065

Table 25 (Phase 2, Objective 1)
Watershed: 1
Summer Season: 1972 (Collection I)

Frass Data (kg. nutrient/hectare)

Trap	Ca	Mg	K	P	S	N
5 [a]						1.171
10 [b]						0.381
15 [c]						0.122
20	3.852	0.187	0.141	0.130	0.119	1.757
25 [d]						
30 [d]						
35 [e]						
40	2.539	0.146	0.157	0.083	0.083	1.082
45	1.571	0.110	0.099	0.057	0.056	0.803
50	1.514	0.097	0.072	0.048	0.048	0.717
Total (Σ)	9.476	0.540	0.469	0.318	0.306	6.033
Mean ($\overline{x}$)	2.369	0.135	0.117	0.080	0.076	0.862
St'd dev (s)	1.095	0.040	0.039	0.037	0.032	0.540

Needle Data

Trap	Ca	Mg	K	P	S	N
5 [a]						5.272
10 [b]						5.354
15 [c]						4.140
20	15.739	0.856	2.701	0.824	0.607	5.557
25 [d]						
30 [d]						
35 [e]						
40	21.700	1.231	4.130	1.211	0.976	8.243
45	12.947	1.051	3.194	0.569	0.527	6.425
50	9.162	0.640	1.324	0.449	0.376	3.595
Total (Σ)	59.548	3.778	11.349	3.053	2.486	38.586
Mean ($\overline{x}$)	14.887	0.944	2.837	0.763	0.622	5.512
St'd dev (s)	5.281	0.254	1.170	0.337	0.255	1.524

a. Trap 5 data for Ca-S are omitted because collection V of the 1973 season did not yield enough frass for the analyses.

b. Trap 10 data for Ca-S are omitted because the limited quantity of frass collected in 1973 allowed for nitrogen analysis only.

c. Trap 15 data for Ca-S were eliminated by the shortage of frass in 1972.

d. Road construction obliterated traps 25 and 30 in 1972.

e. Trap 35 had a large branch in it (possible due to road construction) in 1972.

Table 26 (Phase 2, Objective 1)[a,b]
Watershed: 1
Summer Season: 1973 (Collections III, IV & V)

Frass Data (kg. nutrient/hectare)

Trap	Ca	Mg	K	P	S	N
5						2.266
10						0.358
15						1.083
20	8.963	0.465	1.522	0.370	0.312	3.780
25						
30						
35						
40	4.926	0.284	0.865	0.227	0.198	2.257
45	8.672	0.567	2.427	0.537	0.485	4.394
50	6.666	0.438	0.876	0.285	0.238	3.018
Total (Σ)	29.227	1.754	5.690	1.419	1.233	17.156
Mean ($\overline{x}$)	7.307	0.438	1.422	0.355	0.308	2.451
St'd dev (s)	1.887	0.117	0.737	0.135	0.127	1.425

Needle Data

Trap	Ca	Mg	K	P	S	N
5						7.691
10						6.659
15						6.001
20	21.562	1.334	4.498	1.299	0.967	11.759
25						
30						
35						
40	12.901	0.901	2.955	1.052	0.704	9.122
45	12.607	1.145	3.777	1.094	0.761	10.266
50	14.989	1.058	2.547	0.972	0.684	9.679
Total (Σ)	62.059	4.438	13.777	4.417	3.116	61.177
Mean ($\overline{x}$)	15.515	1.109	3.444	1.104	0.779	8.740
St'd dev (s)	4.169	0.181	0.869	0.139	0.130	2.058

a. See footnotes on Table 25.

b. Values in this table are totals (III + IV + V).

Table 27 (Phase 2, Objective 1)
Watershed: 4
Summer Season: 1972 (Collection I)

Frass Data (kg. nutrient/hectare)

Trap	Ca	Mg	K	P	S	N
5 [a]						0.151
10 [b]						
15						
20						0.010
25						0.086
30						0.134
35						0.082
40	1.669	0.069	0.050	0.050	0.044	0.653
45						0.089
50	0.780	0.045	0.040	0.026	0.028	0.504
Total (Σ)	2.449	0.114	0.090	0.076	0.072	1.709
Mean ($\overline{x}$)	1.224	0.057	0.045	0.038	0.036	0.214
St'd dev (s)	0.629	0.017	0.007	0.017	0.011	0.232

Needle Data

Trap	Ca	Mg	K	P	S	N
5 [a]						1.256
10 [b]						
15						
20						0.971
25						5.641
30						1.857
35						3.245
40	13.524	0.444	1.434	0.323	0.306	4.034
45						2.485
50	13.048	0.874	2.158	0.687	0.607	5.979
Total (Σ)	26.572	1.318	3.592	1.010	0.913	25.468
Mean ($\overline{x}$)	13.286	0.659	1.796	0.505	0.456	3.184
St'd dev (s)	0.337	0.304	0.512	0.257	0.213	1.906

a. Some frass was collected in traps 5, 15-35 and 45 in 1972, but only enough for nitrogen analysis.

b. Traps 10 and 15 data are omitted for all nutrients including nitrogen because of insufficient frass collected in the 1973 season (see Table 18).

Table 28 (Phase 2, Objective 1)[a,b]
Watershed: 4
Summer Season: 1973 (Collections III, IV & V)

Frass Data (kg. nutrient/hectare)

Trap	Ca	Mg	K	P	S	N
5						2.702
10						
15						
20						1.002
25						2.684
30						6.245
35						2.275
40	12.738	0.696	2.459	0.563	0.424	4.476
45						5.588
50	20.454	1.104	4.092	0.895	0.772	9.283
Total (Σ)	33.192	1.800	6.551	1.458	1.196	34.255
Mean ($\overline{x}$)	16.596	0.900	3.276	0.729	0.598	4.282
St'd dev (s)	5.456	0.288	1.155	0.235	0.246	2.684

Needle Data

Trap	Ca	Mg	K	P	S	N
5						4.040
10						
15						
20						2.276
25						15.745
30						4.336
35						5.009
40	33.170	1.164	4.084	1.074	0.856	9.927
45						7.702
50	20.907	1.663	5.776	1.847	1.384	16.545
Total (Σ)	54.077	2.827	9.860	2.921	2.240	65.580
Mean ($\overline{x}$)	27.038	1.414	4.930	1.460	1.120	8.198
St'd dev (s)	8.671	0.353	1.196	0.547	0.373	5.442

a. See footnotes on Table 27.

b. Values in this table are totals (Σ III, IV & V).

Table 29
Mean weight frass/needle deposited per summer season and associated increases
Phase 2, Objective 1

	WS-1(g)[a]	WS-4(g)[b]	WS-1(g)[c]	WS-4(g)[d]
Frass 1972[e]	4.38	2.11	3.45	0.80
Frass 1973[f]	11.66	20.72	8.37	13.20
Increase from 1972	2.7 x	9.8 x	2.4 x	16.4 x
Needles 1972	20.34	15.00	17.43	10.05
Needles 1973	25.00	34.65	21.74	22.06
Increase from 1972	1.2 x	2.3 x	1.2 x	2.2 x

a. Mean weight in grams of material collected from traps 20, 40, 45 and 50 (watershed 1) and analyzed for Ca, Mg, K, P and S.

b. Mean weight in grams of material collected from traps 40 and 50 (watershed 4) and analyzed for Ca, Mg, K, P and S.

c. Mean weight in grams of material collected from traps 5, 10, 15, 20, 40, 45 and 50 (watershed 1) and analyzed for N.

d. Mean weight in grams of material collected from traps 5. 20, 25, 30, 35, 40, 45 and 50 (watershed 4) and analyzed for N.

e. 1972: Collection 1.

f. 1973: Σ collections III, IV and V.

Table 30 (Phase 2, Objective 1)

Deposition Percentages[a]

	Ca(%)	Mg(%)	K(%)	P(%)	S(%)	N(%)
Watershed 1						
Frass '72[b]	13.7	12.5	4.0	9.5	10.9	13.5
Needles '72	86.3	87.5	96.0	90.5	89.1	86.5
Frass '73[c]	32.0	28.3	29.2	24.3	28.3	21.9
Needles '73	68.0	71.7	70.8	75.7	71.7	78.1
Watershed 4						
Frass '72[b]	8.4	8.0	2.4	7.0	7.3	6.3
Needles '72	91.6	92.0	97.6	93.0	92.7	93.7
Frass '73[c]	38.0	38.9	39.9	33.3	34.8	34.3
Needles '73	62.0	61.1	60.1	66.7	65.2	65.7

(a) Mean amount (in kg/ha) of nutrient deposited during the period in the form of either frass or needles divided by the sum of the mean amounts of nutrient deposited during the same period in the two forms x 100. The mean values used are those tabulated in Tables 25 -28 and illustrated in Figures 13 and 14. Note that the number of traps related to the means varies among nutrients and watersheds.

(b) Collection I.

(c) Collections III, IV and V.

Special note regarding Tables 31-42 (Phase 2, Objective 2):

Omissions from Tables 31-42 are due to the small amount of collected frass. If a trap failed to provide enough frass and/or needles for analysis in any one of collections III through V, the complete set of data for that trap was ignored in computing the period means (See Discussion). Data for collection VI for Ca, Mg, K, P and S in frass are omitted entirely for both watersheds 1 and 4 due to shortage of frass and were treated as zeros in calculating percentages of nutrient deposition. Values for N were obtainable and those results are shown.

Table 31 (Phase 2, Objective 2)

Nutrient: Calcium

Watershed: 1

Frass Data (Kg nutrient/hectare)

Trap	III	IV	V	VI
5				
10				
15				
20	1.914	5.710	1.339	
25				
30	1.713	8.859	1.031	
35	5.050	12.149	1.616	
40	0.979	3.268	0.679	
45	2.278	5.523	0.871	
50	1.537	3.928	1.201	
Total (Σ)	13.471	39.437	6.737	
Mean ($\bar{x}$)	2.245	6.573	1.123	
St'd dev (s)	1.440	3.349	0.336	

Needle Data

Trap	III	IV	V	VI
5				
10				
15				
20	1.622	3.336	16.604	38.359
25				
30	0.992	3.808	17.069	32.026
35	2.970	4.284	15.553	38.729
40	1.088	1.540	10.273	21.870
45	1.507	1.870	9.230	11.742
50	0.988	1.762	12.239	30.168
Total (Σ)	9.167	16.600	80.968	172.894
Mean ($\bar{x}$)	1.528	2.767	13.495	28.816
St'd dev (s)	0.756	1.186	3.371	10.404

Table 32 (Phase 2, Objective 2)

Nutrient: Calcium

Watershed: 4

Frass Data (Kg nutrient/hectare)

Trap	III	IV	V	VI
5	0.314	3.406	1.326	
10				
15				
20				
25				
30	1.072	5.658	1.545	
35	0.622	2.773	0.621	
40	2.001	9.373	1.364	
45	0.880	6.864	0.959	
50	6.225	12.470	1.759	
Total (Σ)	11.114	40.544	7.574	
Mean ($\bar{x}$)	1.852	6.757	1.262	
St'd dev (s)	2.217	3.682	0.411	

Needle Data

5	0.612	0.829	6.248	52.814
10				
15				
20				
25				
30	0.494	0.816	5.075	18.882
35	0.580	0.524	7.674	32.614
40	1.044	1.427	30.699	56.583
45	1.045	1.390	10.198	53.447
50	2.677	3.108	15.122	53.913
Total (Σ)	6.452	8.094	75.016	268.253
Mean ($\bar{x}$)	1.075	1.349	12.503	44.709
St'd dev (s)	0.820	0.931	9.601	15.369

Table 33 (Phase 2, Objective 2)

Nutrient: Magnesium

Watershed: 1

Frass Data (Kg nutrient/hectare)

Trap	III	IV	V	VI
5				
10				
15				
20	0.200	0.214	0.051	
25				
30	0.177	0.449	0.036	
35	0.486	0.722	0.063	
40	0.106	0.144	0.034	
45	0.250	0.275	0.042	
50	0.193	0.188	0.057	
Total (Σ)	1.412	1.992	0.283	
Mean ($\overline{x}$)	0.235	0.332	0.047	
St'd dev (s)	0.131	0.219	0.012	

Needle Data

Trap	III	IV	V	VI
5				
10				
15				
20	0.211	0.187	0.936	2.445
25				
30	0.112	0.264	1.125	2.053
35	0.460	0.424	1.065	3.053
40	0.194	0.115	0.592	1.738
45	0.254	0.142	0.749	0.831
50	0.157	0.128	0.773	1.677
Total (Σ)	1.388	1.260	5.240	11.797
Mean ($\overline{x}$)	0.231	0.210	0.873	1.966
St'd dev (s)	0.122	0.118	0.204	0.754

Table 34 (Phase 2, Objective 2)

Nutrient: Magnesium

Watershed: 4

Frass Data (Kg nutrient/hectare)

Trap	III	IV	V	VI
5	0.045	0.392	0.057	
10				
15				
20				
25				
30	0.134	0.484	0.066	
35	0.092	0.193	0.031	
40	0.149	0.516	0.031	
45	0.119	0.621	0.043	
50	0.447	0.587	0.070	
Total (Σ)	0.986	2.793	0.298	
Mean ($\bar{x}$)	0.164	0.465	0.050	
St'd dev (s)	0.143	0.156	0.017	

Needle Data

Trap	III	IV	V	VI
5	0.095	0.104	0.397	1.394
10				
15				
20				
25				
30	0.076	0.081	0.232	0.883
35	0.078	0.052	0.530	1.799
40	0.107	0.108	0.949	1.800
45	0.111	0.116	0.526	3.022
50	0.427	0.296	0.940	2.396
Total (Σ)	0.894	0.757	3.574	11.294
Mean ($\bar{x}$)	0.149	0.126	0.596	1.882
St'd dev (s)	0.137	0.086	0.291	0.750

Table 35 (Phase 2, Objective 2)

Nutrient: Potassium

Watershed: 1

Frass Data (Kg nutrient/hectare)

Trap	III	IV	V	VI
5				
10				
15				
20	0.860	0.586	0.076	
25				
30	0.875	1.678	0.052	
35	2.085	2.471	0.063	
40	0.481	0.332	0.052	
45	1.455	0.894	0.078	
50	0.526	0.290	0.060	
Total (Σ)	6.282	6.251	0.381	
Mean ($\bar{x}$)	1.047	1.042	0.064	
St'd dev (s)	0.616	0.866	0.113	

Needle Data

Trap	III	IV	V	VI
5				
10				
15				
20	1.270	0.705	2.523	6.604
25				
30	0.623	1.078	2.501	5.102
35	2.549	2.047	1.671	6.394
40	1.111	0.430	1.414	3.272
45	1.675	0.606	1.496	1.488
50	0.808	0.399	1.340	3.024
Total (Σ)	8.036	5.265	10.945	25.884
Mean ($\bar{x}$)	1.339	0.878	1.824	4.314
St'd dev (s)	0.697	0.623	0.544	2.046

Table 36 (Phase 2, Objective 2)

Nutrient: Potassium

Watershed: 4

Frass Data (Kg nutrient/hectare)

Trap	III	IV	V	VI
5	0.169	1.353	0.077	
10				
15				
20				
25				
30	0.718	3.002	0.125	
35	0.389	0.569	0.036	
40	0.520	1.892	0.047	
45	0.725	3.607	0.075	
50	1.906	2.088	0.098	
Total (Σ)	4.427	12.511	0.458	
Mean ($\bar{x}$)	0.738	2.085	0.076	
St'd dev (s)	0.610	1.098	0.033	

Needle Data

5	0.560	0.453	0.669	2.204
10				
15				
20				
25				
30	0.501	0.391	0.806	1.775
35	0.450	0.182	0.779	3.671
40	0.694	0.516	2.874	3.109
45	0.713	0.616	2.271	7.632
50	2.477	1.069	2.230	3.307
Total (Σ)	5.395	3.227	9.629	21.698
Mean ($\bar{x}$)	0.899	0.538	1.605	3.616
St'd dev (s)	0.780	0.298	0.963	2.091

Table 37 (Phase 2, Objective 2)

Nutrient: Phosphorus

Watershed: 1

Frass Data (Kg nutrient/hectare)

Trap	III	IV	V	VI
5				
10				
15				
20	0.171	0.159	0.040	
25				
30	0.178	0.367	0.032	
35	0.408	0.520	0.046	
40	0.095	0.106	0.026	
45	0.280	0.218	0.039	
50	0.145	0.100	0.040	
Total (Σ)	1.277	1.470	0.223	
Mean ($\bar{x}$)	0.213	0.245	0.037	
St'd dev (s)	0.113	0.167	0.007	

Needle Data

5				
10				
15				
20	0.278	0.233	0.788	2.660
25				
30	0.149	0.290	0.752	2.051
35	0.610	0.549	0.784	3.125
40	0.276	0.174	0.602	1.987
45	0.389	0.234	0.471	0.952
50	0.220	0.180	0.572	1.961
Total (Σ)	1.922	1.660	3.969	12.736
Mean ($\bar{x}$)	0.320	0.277	0.662	2.123
St'd dev (s)	0.162	0.140	0.132	0.737

Table 38 (Phase 2, Objective 2)

Nutrient: Phosphorus

Watershed: 4

Frass Data (Kg nutrient/hectare)

Trap	III	IV	V	VI
5	0.032	0.264	0.035	
10				
15				
20				
25				
30	0.256	0.626	0.056	
35	0.092	0.116	0.021	
40	0.128	0.409	0.026	
45	0.138	0.670	0.032	
50	0.415	0.426	0.054	
Total (Σ)	1.061	2.511	0.224	
Mean ($\overline{x}$)	0.177	0.418	0.037	
St'd dev (s)	0.138	0.211	0.015	

Needle Data

5	0.135	0.111	0.227	1.655
10				
15				
20				
25				
30	0.120	0.115	0.286	1.354
35	0.119	0.068	0.312	2.382
40	0.165	0.141	0.768	1.961
45	0.185	0.164	0.558	3.658
50	0.591	0.388	0.868	2.571
Total (Σ)	1.315	0.987	3.019	13.581
Mean ($\overline{x}$)	0.219	0.164	0.503	2.264
St'd dev (s)	0.184	0.114	0.271	0.818

Table 39 (Phase 2, Objective 2)

Nutrient: Sulfur

Watershed: 1

Frass Data (Kg nutrient/hectare)

Trap	III	IV	V	VI
5				
10				
15				
20	0.102	0.167	0.043	
25				
30	0.155	0.371	0.033	
35	0.274	0.422	0.045	
40	0.061	0.108	0.029	
45	0.170	0.278	0.037	
50	0.077	0.112	0.039	
Total (Σ)	0.839	1.458	0.226	
Mean ($\overline{x}$)	0.140	0.243	0.038	
St'd dev (s)	0.078	0.135	0.006	

Needle Data

5				
10				
15				
20	0.150	0.185	0.632	2.205
25				
30	0.082	0.205	0.705	1.674
35	0.370	0.355	0.611	2.422
40	0.137	0.111	0.456	1.585
45	0.196	0.146	0.419	0.913
50	0.125	0.129	0.430	1.751
Total (Σ)	1.060	1.131	3.253	10.550
Mean ($\overline{x}$)	0.177	0.188	0.542	1.758
St'd dev (s)	0.102	0.089	0.122	0.528

Table 40 (Phase 2, Objective 2)

Nutrient: Sulfur

Watershed: 4

Frass Data (Kg nutrient/hectare)

Trap	III	IV	V	VI
5	0.025	0.217	0.045	
10				
15				
20				
25				
30	0.108	0.446	0.054	
35	0.059	0.118	0.022	
40	0.089	0.305	0.030	
45	0.077	0.469	0.032	
50	0.306	0.406	0.060	
Total (Σ)	0.664	1.981	0.243	
Mean ($\bar{x}$)	0.111	0.330	0.040	
St'd dev (s)	0.100	0.143	0.015	

Needle Data

5	0.055	0.064	0.206	1.496
10				
15				
20				
25				
30	0.053	0.083	0.271	1.241
35	0.060	0.056	0.349	1.987
40	0.087	0.097	0.672	1.833
45	0.099	0.108	0.460	3.135
50	0.319	0.309	0.756	2.250
Total (Σ)	0.673	0.717	2.714	11.942
Mean ($\bar{x}$)	0.112	0.120	0.452	1.990
St'd dev (s)	0.103	0.095	0.221	0.665

Table 41 (Phase 2, Objective 2)

Nutrient: Nitrogen

Watershed: 1

Frass Data (Kg nutrient/hectare)

Trap	III	IV	V	VI
5	0.780	1.270	0.216	0.018
10	0.077	0.210	0.071	0.024
15	0.267	0.697	0.119	0.253
20	1.160	2.061	0.559	0.059
25				
30	1.117	3.914	0.450	0.051
35	2.518	5.036	0.677	0.054
40	0.549	1.352	0.356	0.121
45	1.418	2.486	0.490	0.060
50	0.833	1.561	0.624	0.197
Total (Σ)	8.719	18.587	3.562	0.837
Mean ($\bar{x}$)	0.969	2.065	0.396	0.093
St'd dev (s)	0.723	1.546	0.220	0.081

Needle Data

5	1.162	1.045	5.484	17.931
10	1.319	1.239	4.101	12.661
15	0.931	0.910	4.160	20.749
20	2.083	2.303	7.373	25.011
25				
30	1.046	2.552	7.891	19.762
35	4.874	4.881	8.185	18.659
40	2.025	1.944	5.153	18.518
45	2.740	2.348	5.178	10.238
50	1.667	1.873	6.139	20.254
Total (Σ)	17.847	19.095	53.664	163.783
Mean ($\bar{x}$)	1.983	2.122	5.963	18.198
St'd dev (s)	1.232	1.193	1.537	4.388

Table 42 (Phase 2, Objective 2)

Nutrient: Nitrogen

Watershed: 4

Frass Data (Kg nutrient/hectare)

Trap	III	IV	V	VI
5	0.221	1.900	0.581	0.089
10				
15				
20	0.579	0.338	0.085	0.053
25	0.096	2.190	0.398	0.068
30	1.160	4.307	0.778	0.156
35	0.596	1.380	0.299	0.153
40	0.830	3.222	0.424	0.087
45	0.725	4.397	0.466	0.086
50	3.362	5.126	0.795	0.077
Total (Σ)	7.569	22.860	3.826	0.769
Mean ($\bar{x}$)	0.946	2.858	0.478	0.096
St'd dev (s)	1.032	1.675	0.238	0.038

Needle Data

Trap	III	IV	V	VI
5	0.890	0.871	2.279	18.521
10				
15				
20	0.676	0.626	0.974	5.229
25	2.133	2.281	11.331	16.929
30	0.703	0.919	2.714	13.905
35	0.822	0.664	3.523	23.676
40	1.146	1.176	7.605	17.690
45	1.322	1.372	5.008	32.348
50	3.422	3.864	9.259	26.065
Total (Σ)	11.114	11.773	42.693	154.363
Mean ($\bar{x}$)	1.389	1.472	5.337	19.295
St'd dev (s)	0.949	1.103	3.686	8.204

Table 43, (Phase 2, Objective 2)

Watershed 1

Material	Collection Period	Deposition Percentages[a] Ca(%)	Mg(%)	K(%)	P(%)	S(%)	N(%)
Frass	III	59.5	50.4	43.9	40.0	44.2	32.8
Needles	III	40.5	49.6	56.1	60.0	55.8	67.2
Frass	IV	70.4	61.3	54.3	46.9	56.4	49.3
Needles	IV	29.6	38.7	45.7	53.1	43.6	50.7
Frass	V	7.7	5.1	3.4	5.3	6.6	6.2
Needles	V	92.3	94.9	96.6	94.7	93.4	93.8
Frass	Σ III-V	35.8	31.8	34.8	28.2	31.7	25.4
Needles	Σ III-V	64.2	68.2	65.2	71.8	68.3	74.6
Frass	VI	---	---	---	---	---	0.5
Needles	VI	100	100	100	100	100	99.5
Frass	Σ IV-VI	14.5	11.0	13.6	8.4	10.1	8.9
Needles	Σ IV-VI	85.5	89.0	86.4	91.6	89.9	91.1

a. Mean amount (in kg/ha) of nutrient deposited during the designated period in the form of either frass of needles divided by the sum of the mean amounts of nutrient deposited during that period in the two forms x 100. The mean values used are those tabulated in Tables 31-42.

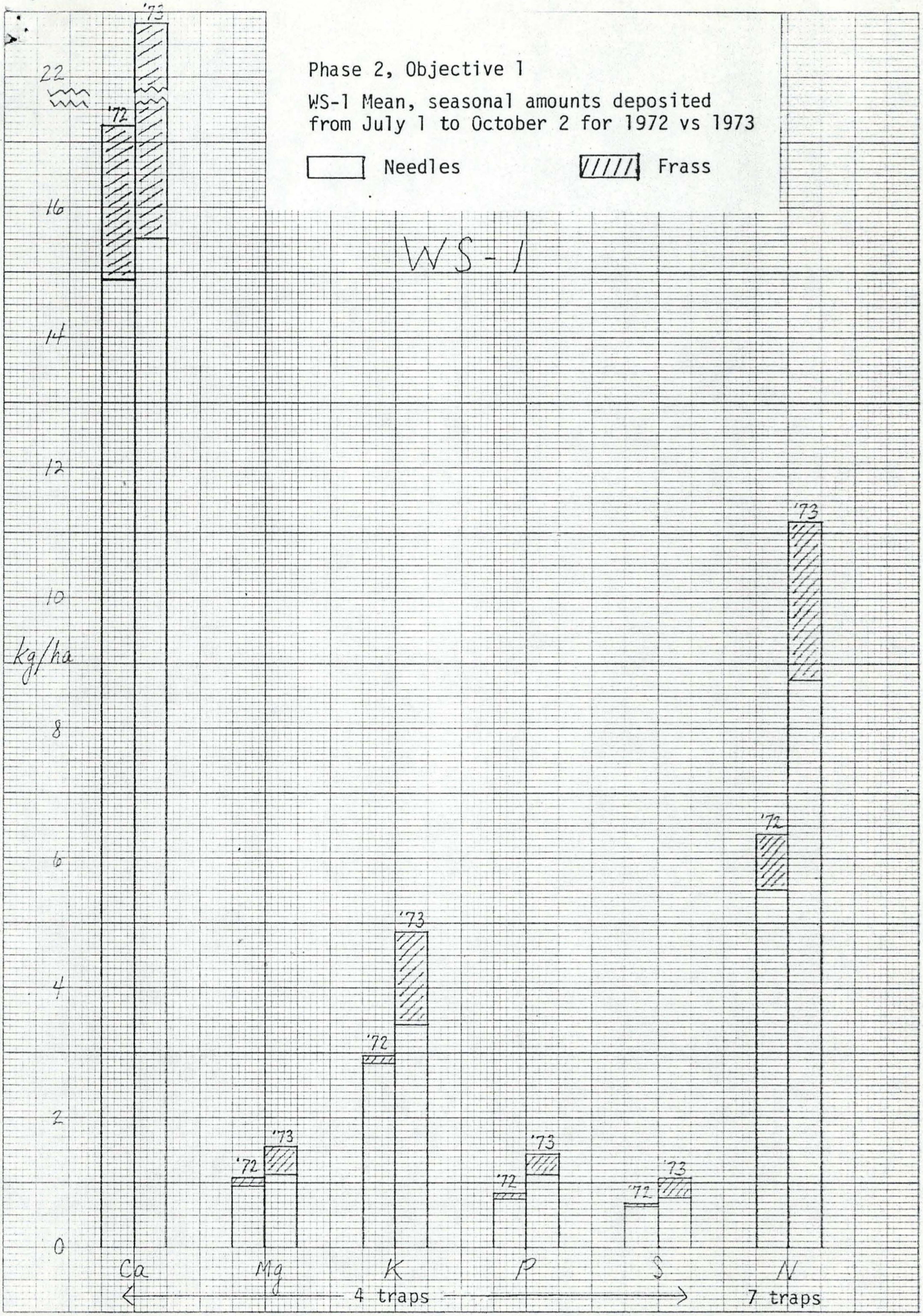
Table 44, (Phase 2, Objective 2)

Watershed 4

		Deposition Percentages[a]					
Material	Collection Period	Ca(%)	Mg(%)	K(%)	P(%)	S(%)	N(%)
Frass	III	63.3	52.4	45.1	44.7	49.8	40.5
Needles	III	36.7	47.6	54.9	55.3	50.2	59.5
Frass	IV	83.4	78.7	79.5	71.8	73.3	66.0
Needles	IV	16.6	21.3	20.5	28.2	26.7	34.0
Frass	V	9.2	7.7	4.5	6.9	8.1	8.2
Needles	V	90.8	92.3	95.5	93.1	91.9	91.8
Frass	Σ III-V	39.8	43.8	48.8	41.6	41.3	34.3
Needles	Σ III-V	60.2	56.2	51.2	58.4	58.7	65.7
Frass	VI	---	---	---	---	---	0.8
Needles	VI	100	100	100	100	100	99.2
Frass	Σ IV-VI	12.0	16.5	27.2	13.4	12.6	11.6
Needles	Σ IV-VI	88.0	83.5	72.8	86.6	87.4	88.4

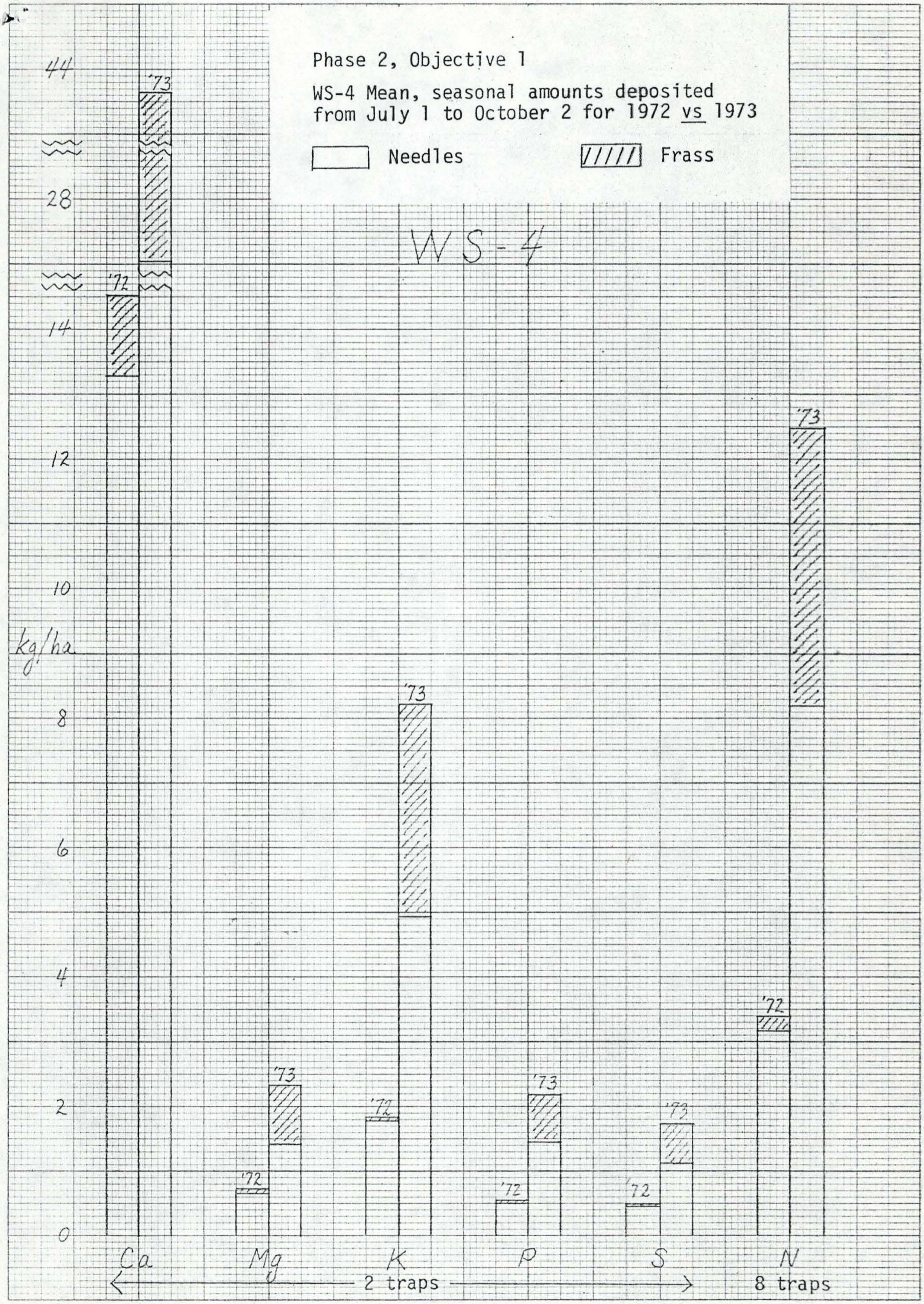
a. Mean amount (in kg/ha) of nutrient deposited during the designated period in the form of either frass or needles divided by the sum of the mean amounts of nutrient deposited during that period in the two forms x 100. The mean values used are those tabulated in Tables 31-42.

Figure 13



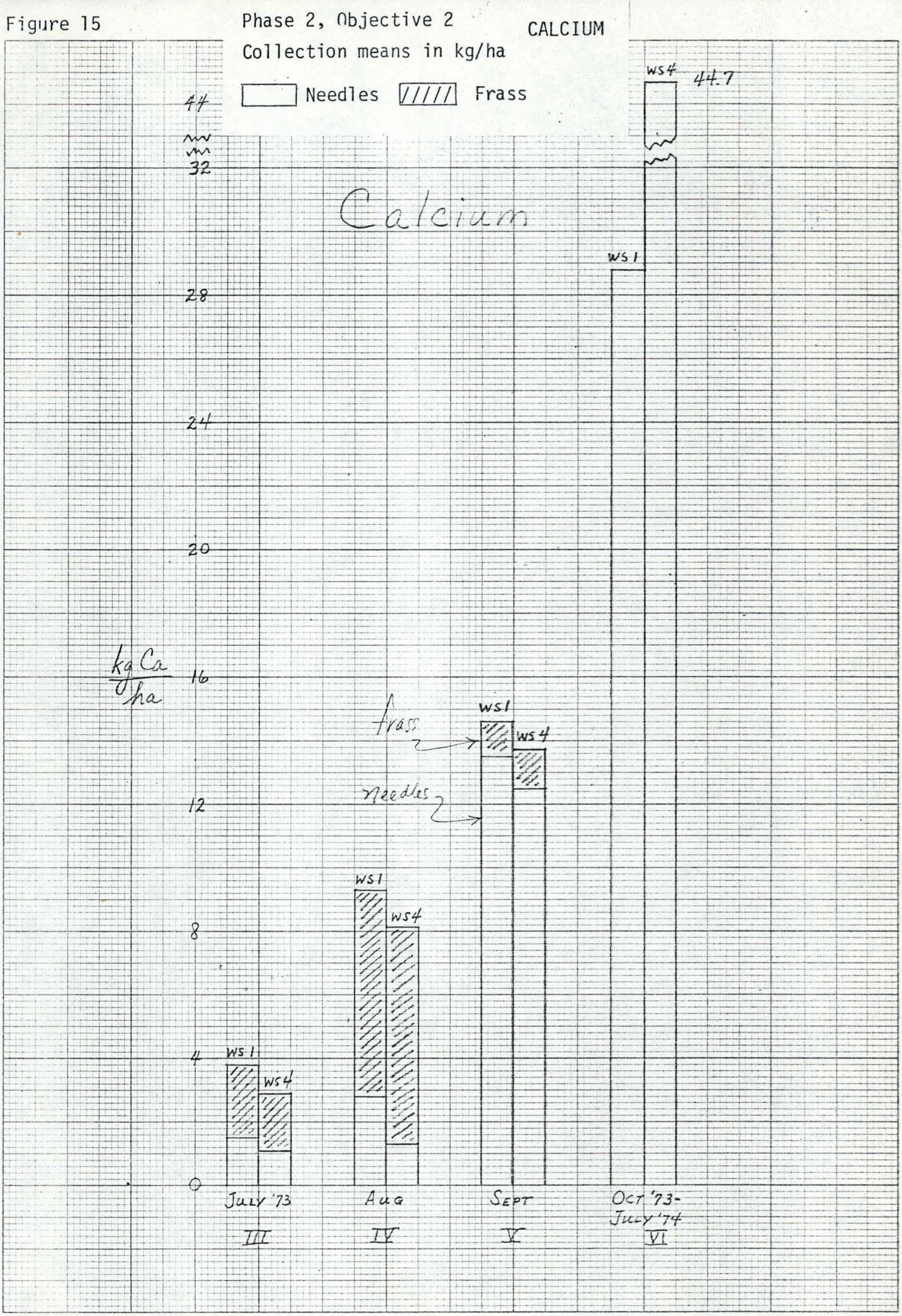
Phase 2, Objective 1
WS-1 Mean, seasonal amounts deposited from July 1 to October 2 for 1972 vs 1973
Needles
Frass
WS-1
kg/ha
22
16
14
12
10
8
6
4
2
0
'72
'73
Ca
Mg
K
P
S
N
4 traps
7 traps

Figure 14



Phase 2, Objective 1
WS-4 Mean, seasonal amounts deposited from July 1 to October 2 for 1972 vs 1973
Needles
Frass
WS-4
kg/ha
44
28
14
12
10
8
6
4
2
0
'72
'73
Ca
Mg
K
P
S
N
2 traps
8 traps

Figure 15



Phase 2, Objective 2
Collection means in kg/ha
Needles
Frass
CALCIUM
Calcium
kg Ca / ha
44
32
28
24
20
16
12
8
4
0
ws4
44.7
ws1
frass
needles
ws1
ws4
ws1
ws4
ws1
ws4
July '73
Aug
Sept
Oct '73-July '74
III
IV
V
VI

Figure 16

Phase 2, Objective 2

Collection means in kg/ha

MAGNESIUM

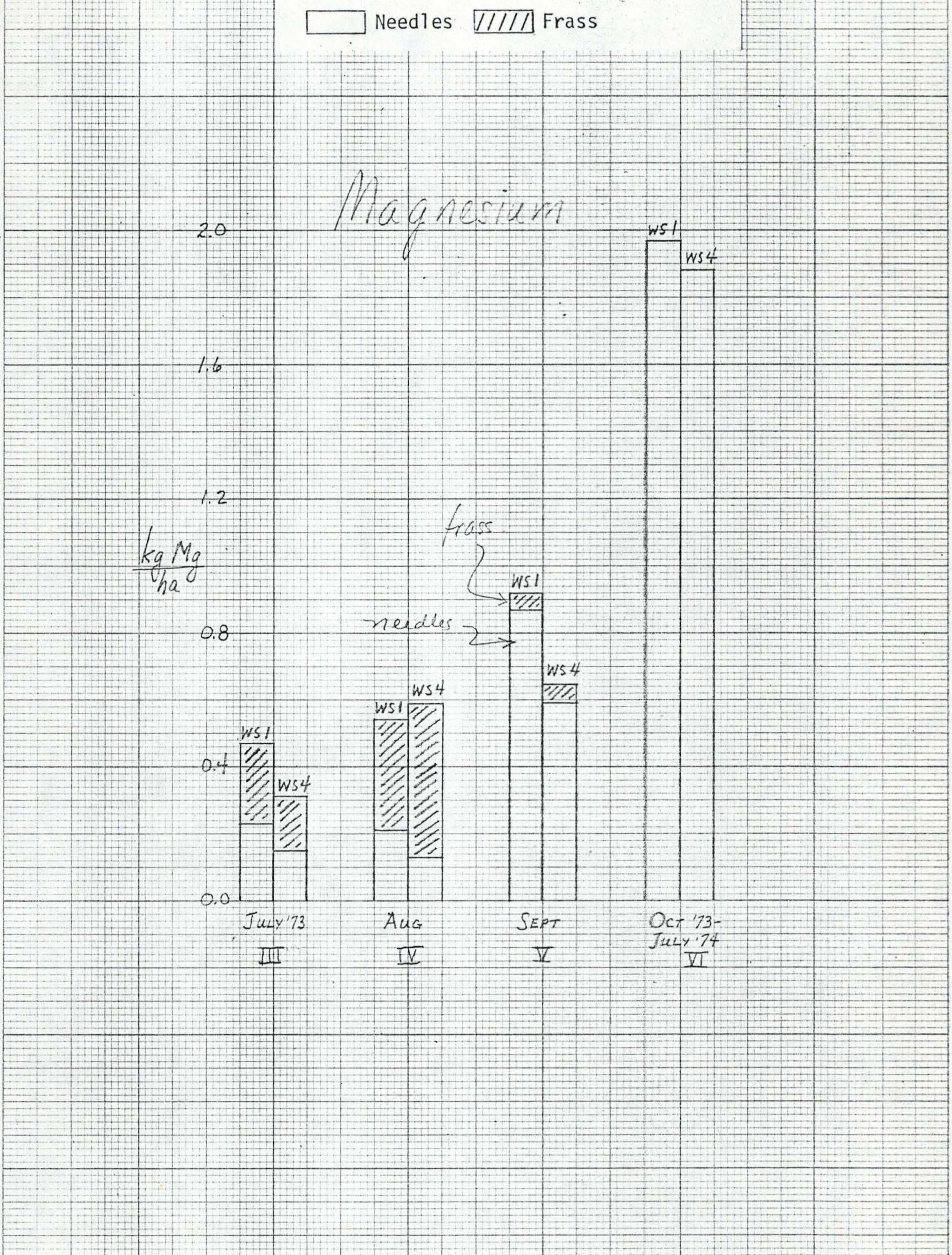
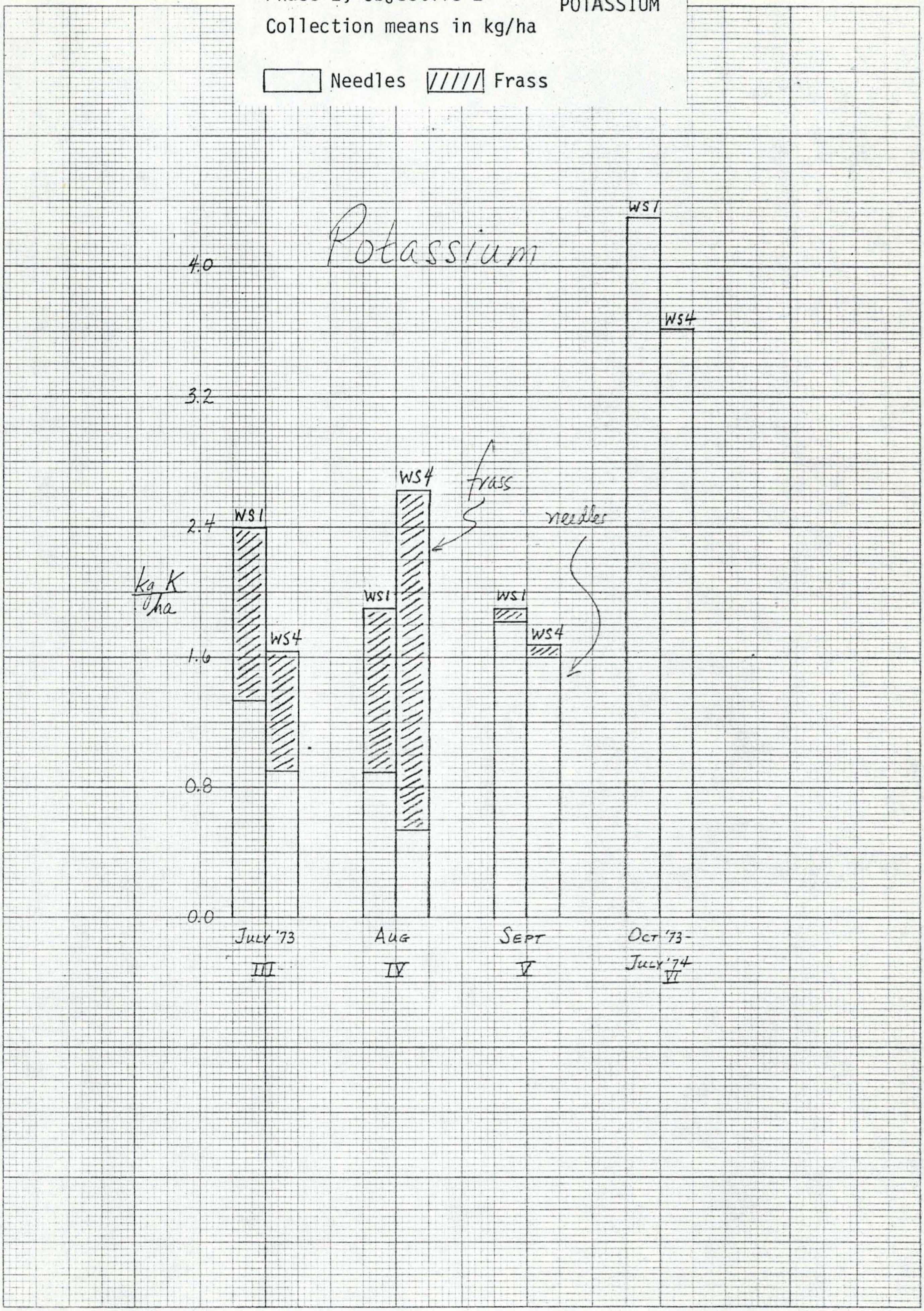


Figure 17



Phase 2, Objective 2
Collection means in kg/ha
POTASSIUM
Needles
Frass
Potassium
kg K / ha
4.0
3.2
2.4
1.6
0.8
0.0
WS1
WS4
frass
needles
July '73
III
Aug
IV
Sept
V
Oct '73-
July '74
VI

Figure 18

Phase 2, Objective 2

Collection means in kg/ha

———— Needles ///// Frass

PHOSPHORUS

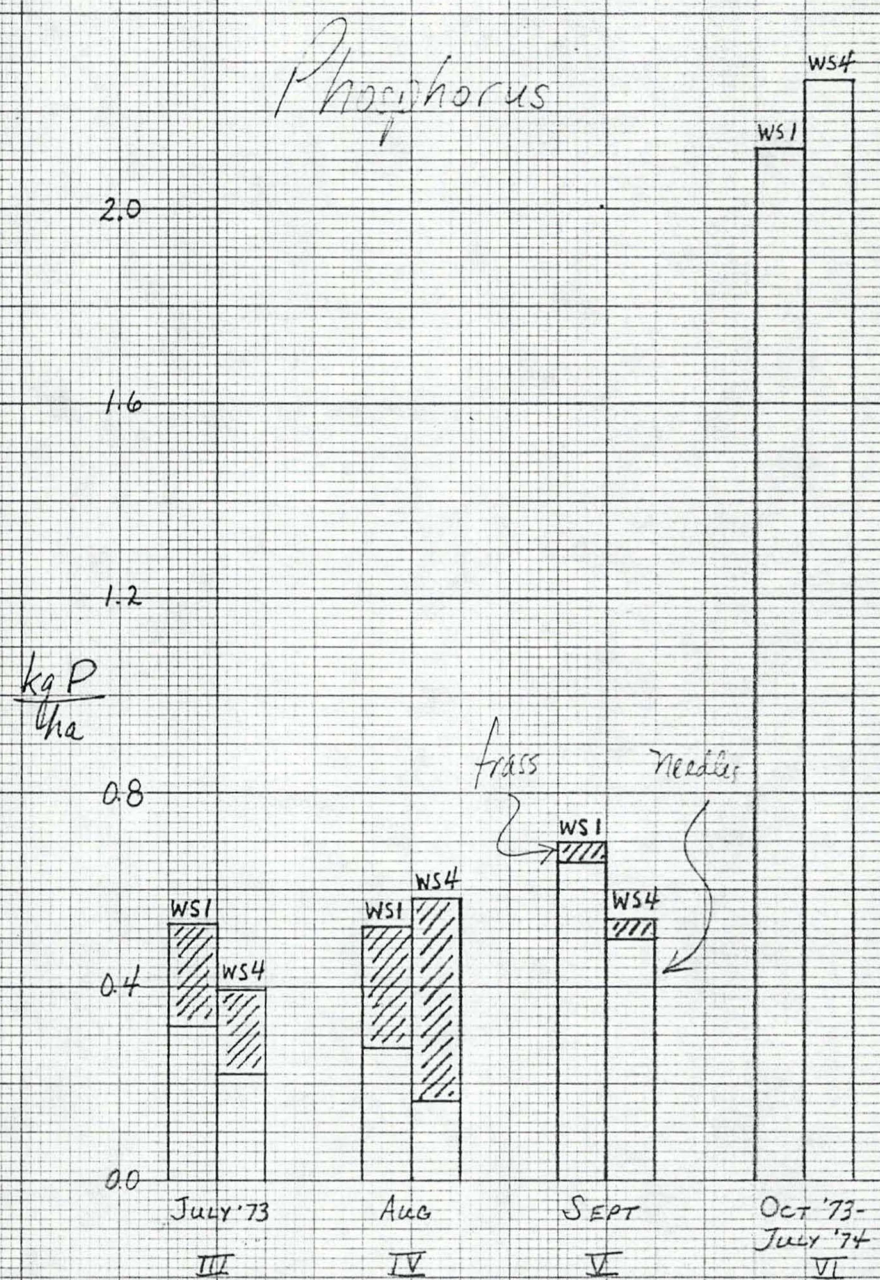


Figure 19

Phase 2, Objective 2

Collection means in kg/ha

SULFUR

Needles /////Frass

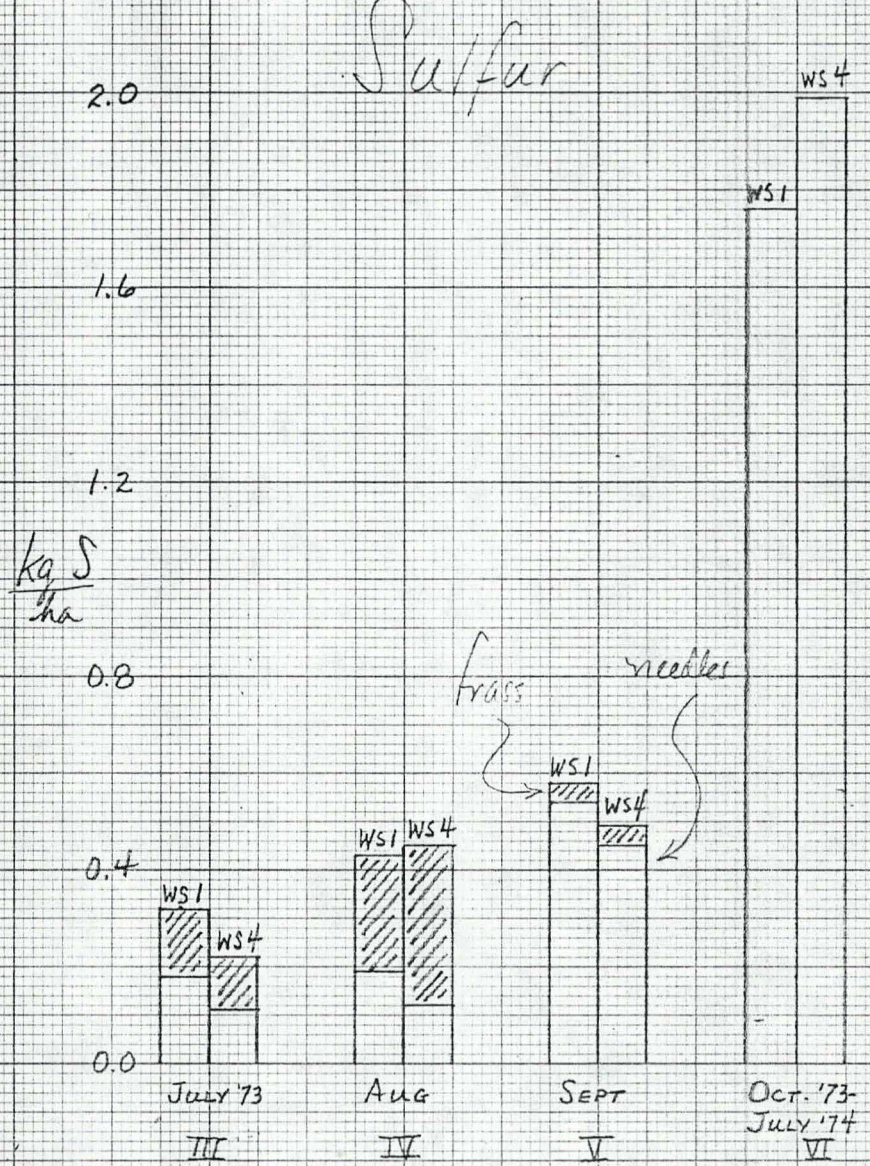


Figure 20

Phase 2, Objective 2

Collection means in kg/ha

NITROGEN

Needles //// Frass